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CIVIL AND MECHANICAL ENGINEERING.

On Incrustation of Marine Boilers. By Mr. P. Jensen.

From the London Mechanics' Magazine, May, 1866.

Concluded from page 86.

We come now to a brief survey of the various means proposed or adopted for preventing incrustation. They consist in—

1. Surface condensers.

2. By heating the feed-water to such a temperature before entering the boiler as to oblige the sulphate of lime, and other salts, to accumulate in the heater only.

3. By introducing various substances into the feed-water, before entering the boiler, the feed-water at the same time being subjected to heat so as to throw down the salts without allowing the same to enter the boiler.

4. By introducing various substances into the boiler so as to neutralize the effect of the salts, and

5. By blowing off in the usual or various other ways.

1. *Surface condensers.*—This seems at once to do away with the nuisance. The economy anticipated has not, however, been quite realized in practice. It has been found necessary to inject a little salt water along with the distilled water from the condenser, and the duration of the boiler has been found, in many cases, to be even shorter than with salt water, the reasons for which it is not thought necessary to enter into here.

2. Heating the feed-water, before entering the boiler, to such a degree that the salts are supposed to be thrown down in the heater in-

stead of the boiler. This looks very feasible, but, after all, it amounts to shifting an evil from one place to another; let the heater be choked with salt and incrustation and the engineer in charge has his hands as full as ever. To be admissible on board ship it must be compact, and, at the same time, accessible for thorough scaling, two conditions not very easily reconciled. The most practical shape is that of a casing with a number of dishes or shelves piled on the top of each other in the same, which can be taken out and replaced by clean ones in a short space of time. This plan has been patented by Mr. Spencer (No. 896), and in 1864 (No. 86) by M. L. E. E. Martin, a French gentleman. It is possible that this idea, by no means novel, possesses practical value, and, at some future time, may prove successful.

3. The plan of medicating the feed-water in a heater before it is admitted to the boiler, feasible and correct in principle as it appears, resolves itself, however, into a commercial question, and is contingent upon the price and bulk and other qualities of the substances proposed to be used for neutralizing the salts contained in the feed-water. Many substances have been proposed for this purpose, some evidently not of a harmless character as regards the iron plates of the heater, some evidently so expensive as to be out of the question, and only one or two are of a really feasible character. This latter class will be treated under the next head.

4. The plan of admitting foreign substances into the boiler to neutralize the salts, or some of them contained in the sea-water, has found favor with a great many inventors. Suffice it to say that nothing has appeared more likely, in the eyes of practical and scientific gentlemen, than soda. Mr. J. R. Napier has gone into an estimate of the commercial advantage of using soda-ash for preventing incrustations. He assumes the boiler to work at 270° = 26 lbs. per square inch, and evaporating at that temperature 7½ lbs. water from 100° per lb. of coal. The following is his table:

	Mechanical method.	Chemical method.
Sea-water supplied to boiler at 100°	15 lbs.	8·33
Water discharged at 270°	7·5 lbs.	·83
Water evaporated	7·5 lbs.	7·5
Total heat evaporated from— 100° at 270° = 1092 × 5-10th (T_1 32—T_2 32) = 1095	8215·5	8215·5°
Heat discharged	1275°	142°
Heat consumed in evaporation	1 lb.	1 lb.
Fuel consumed in preventing crust	·155 lb. coal.	{ ·0172 lb. coal × ·0085 lb. soda-ash.
Total fuel	1·155 lb. coal.	{ 1·017 lb. coal × ·0085 lb. soda-ash.

Thus it seems, he says, that it requires only 172 lbs. of coal + 85 lbs. of soda-ash containing 50° of soda to be as efficient in preventing crust, as 1·550 lb. of coal alone, which evaporates 7½ lbs. of water

from 100° at 270°. And these methods are equally expensive when soda-ash is 16 2 times dearer than coal. This ratio varies with the efficiency of the fuel and the temperature of the evaporation. In this instance the loss by blowing off amounts to 14 per cent. Now, there is no doubt that soda is a very good remedy against incrustations, and it has been repeatedly recommended by eminent chemists. Unfortunately, even this remedy, so simple and efficacious as it has proved, has its drawback, and that of a very serious nature. In a German scientific periodical, *Dingler's Journal*, volume 130, page 153, A. D. 1853, we find it mentioned that Professor R. Fresenius had recommended the use of a certain quantity of soda as a certain and cheap means for preventing incrustations where water is used that contains sulphate of lime (or plaster of Paris). He had used it some months, and with very good results. The factory boiler in question, that formerly used to be scaled at proportionately short intervals, now remained perfectly clean, and even patches of old incrustation too hard for removal had disappeared. But repeated trials and careful examinations had shown that a continued use of soda attacked the boiler-plates very much. Dr. Zimmerman thought that all commercial soda contained more or less cyan, and that this is the reason of the corrosion of the plate. Dr. Rudolph Böttger, who mentions this fact in his *Polytechnisches Notizblatt* of 1853, (No. 20,) says, that he has made several experiments himself, according to which all commercial soda, even from the most respectable firms, contain cyannatrium, and, in consequence of this discovery, he warns others against using it in boilers for the purpose of preventing incrustations. It is important to bear this fact in mind at a time when we find the chief inspector of the Manchester Boiler Association recommending the use of soda in steam boilers. Besides, it must be remembered that such foreign bodies introduced in the boiler produce priming with all its evils.

5. *Blowing off.*—The original practice at sea was, it is believed, to blow off from the bottom only, which was not found efficacious. Subsequently, additional blowing off from the surface was resorted to, and this first at stated intervals and subsequently continuously. Thus we find Henry Maudslay and Joshua Field already in 1824 taking out a patent (No. 5021) for withdrawing a fixed quantity of brine by meters of any kind; they preferred a pump with a loaded discharge-valve drawing from the lowest part of the boiler. They also in this patent mention a tubular regenerator for heating the feed-water by means of the heat of the brine drawn off. These brine pumps were at one time used to some extent, but have now been superseded by the surface blow-off system, because it was found that the pumps and the regenerator got choked with salt and thus became inefficient. Blowing off from the bottom has now become almost superseded by surface b o v-ing off, because the latter plan has been found the more efficient of the two. The impurities contained in the sea-water being, by the application of the heat of the furnace, brought out from the state of chemical solution into that of mechanical mixture in minute particles, floating about in the hot water and steam, are, by the circulation of the steam

and water, floated to the surface in or along with the globules of steam rising to the surface and there held in suspension in the bath of steam and water till accumulating to such an extent as to subside to the bottom, or in their downward course adhering to the surfaces coming in their way. It is hence obvious enough why it has been found advantageous to catch these impurities before they can do any harm and blow them off. Intimately connected with the question of blowing off, is that of sediment collectors. Various sorts have been proposed for this purpose; but it is not proposed to enter into this subject, for the reason that, applicable as they might be for many other sorts of boilers, they are not so, in the author's opinion, as regards marine tubular boilers as now universally adopted, except in the shape of one or two common scum-pans, because any comprehensive system of pipes, pans, and vessels of any sort in the water-room above the tubes would impede the free circulation of the ascending and descending currents, and thus, probably, do more harm than good. The author is, however, open to correction in these remarks, by practical men having actually tried such appliances. And this leads to the consideration of probably the most important element in the prevention of incrustation in marine boilers, viz: the influence that the construction of the boiler itself has upon the subject.

If, as has been shown in the foregoing remarks, the sulphate of lime becomes all but insoluble in sea-water at a pressure of 20 lbs. per square inch above the atmosphere, such as is now commonly used in marine boilers, and if it is a fact, nevertheless, that incrustation can be prevented in some boilers by means of proper and assiduous care, while no amount of care will prevent it in others, then we must arrive at the conclusion that the construction of the boiler, next to the proper and convenient means of constantly observing the state of the water and careful attention to it, forms the most important point in this inquiry. You may build marine boilers of very much the same general internal and external appearance to a superficial observer, and still one is a good and the other is a bad boiler to keep clean and to scale. It is obvious that it is only by the rapid and free circulation of the water and steam that we are enabled to work with salt water at all. It is further probable that, but for the circumstance that the circulation becomes more rapid as you increase the working pressure, and consequently the temperature, higher pressures than 20 lbs., going even as high as 40 lbs., have been found practicable with salt water. The chief principle to be aimed at seems this—wherever the greatest heat is communicated to the plates there also ought to be the greatest facility given for a rapid circulation; and, secondly, make the boiler accessible in all its internal parts, and especially in those most vital, viz: those in which scale, when formed, is most injurious and dangerous, which are those exposed to the greatest heat. The scanty room generally allotted to marine boilers, makes it a difficult task for the designer to meet the above requirements without, at the same time, losing sight of other important considerations, such as economy and strength. The common multitubular marine boiler may be so designed

—and this does not happen very often—that it may give little trouble to the engineer in charge to keep clean and scale it—the tubes must not be too close upon each other, and not too many rows in the vertical line; ample room must be left for a man to get in to clean the furnace crown, the back tube-plate, and the spaces between the tubes. The plan of inclining the back tube-plate somewhat, so as to allow the steam to escape more freely from the same, has found favor with many engineers, and has also collateral advantages. Of late years a multitubular boiler of another description, the vertical water-tube boiler, by Mr. Martin, a chief engineer of the United States Navy, has become extensively adopted in the United States Navy, and possesses, no doubt, advantages as regards scaling the tubes, the water being in them, and the heated products of combustion passing outside and amongst them. This circumstance renders them more easily scaled inside with circular scrapers than is practicable with the tubes in our common marine boilers, that want scaling outside and never can be effectually scaled by mere mechanical means. The Field boiler, now well known amongst engineers, and, because of the very rapid circulation in the tubes possessing the important advantage of keeping the tubes themselves, and also the tube-plate in which they are inserted, free from scale, ought to do well for marine purposes, one should think, although, of course, practice will answer that question. In American men-of-war, where they seem to be able to afford more boiler space than in the British Navy, is often used a long circular return-tube boiler, the tubes being of large diameter (say 1 ft. or more), with very ample water-spaces around and between them. They are, on account of their shape, capable of working with 30 lbs. to 40 lbs. per square inch almost without staying, and also to use salt water at high pressure. Many other boilers proposed or adopted for marine purposes might be mentioned, but it would be to travel beyond the subject to go into the details of this question. To illustrate the importance that has, at all times, attached to this subject, the author here enumerated the more prominent patents that have been taken out in this country for preventing incrustation in boilers. Our limited space only enables us to note a few of the many propositions advanced.

R. B. Lindsay, 1856, (No. 879.)—Applies highly heated steam or air to cause the incrustation to crack, the boiler being cold at the commencement of the process. This method has been tried with great success in the Royal Navy, and seems to offer great advantages wherever it can be applied.

A. C., L. C., and J. L. Casartelli, 1856, (No. 2623.)—A salinometer consisting of two tubes, the ends of which are supported in two cocks. One cock is marked "blow," and the opposite one "limit." Each tube contains a bead or flow adjusted to certain gravities, that in tube "blow" being lightest. When density of water reaches the gravity of float in tube "blow," the same will rise in tube and indicate that more feed should be admitted, but the float in tube "limit" will not rise till density exceed that of the other to a certain extent. When float in tube "limit" rises, water should be fed in to prevent too great density.

This instrument may also be used as a water-gauge. The annexed plan is not unlike Seaward's salinometer patented many years ago.

Mr. R. Armstrong, 1861, (No. 1472.)—His patent consists of a boiler with a vertical circular fire-box, with oval cross-tubes, whose longest axes are horizontal in the centre and vertical at the end. He has also a plan for a feed-water heater consisting of a cast iron cistern, serving as foundation for boiler to stand on, and the heat radiating from the furnace heats the feed-water. This case is divided into two unequal parts by a partition across reaching to within half an inch of cover or lid, which is to have a thick projecting convexity to dip at least one inch below the surface of water when the larger part is fully charged with feed-water. The water expanding at the surface gradually passes over to top of partition to smaller part; the sediment settles in the larger part. He lines or lags inside of shell with wooden staves, to prevent incrustation.

Mr. R. Needham, 1861, (No. 3285.)—A longitudinal pipe at the bottom of boiler connected to a cock or valve outside. The pipe has, at the bottom, an aperture for entrance of mud and sediment, and at top a number of vertical pipes, each with ventilator-shaped funnel at water-line, with mouth turning towards front of boiler, the flow of water being from the front to the back.

Mr. G. Spencer, 1862, (No. 896.)—On some convenient part of boiler in connexion with the steam-space, a close vessel furnished with a lot of diaphragms or dishes placed one over the other; through the centre or sides of each vessel he brings the feed-water pipe, so that it discharges into the top dish, from which it flows down from one to another through holes or spaces, with raised edges not quite so deep as raised edges round edge of dish. The whole interior is in contact with steam from the boiler. In addition he coats the inside of the vessel and dishes, and the inside of the boiler, with a suitable substance, such as Green's oxide paint, to prevent adhesion of deposited salts to the metal.

After this brief notice of the more prominent patents, it is intended, in conclusion, to mention some of the well-known constructions of salinometers; for if it be true, as seems to be the prevailing opinion among marine engineers, and as it has been shown in the foregoing, that, after all, we must depend more upon blowing off than anything else to prevent incrustation in marine boilers, then the salinometer deserves more than a passing notice. One of the first in order of time is that invented twenty-six years ago by the late eminent engineer, Mr. Samuel Seaward. The instrument consisted of a strong glass tube, about ¾ in. bore and 14 ins. long, fixed at each end in a brass frame, to which are attached four cocks, one at each end and two at the side. By the two latter cocks the instrument is attached to the front of the boiler at such a height that the water in the boiler may fill the glass tube. On opening the two cocks attached to the boiler, the water will rise from the bottom of the same by a pipe from the lower cock and fill the glass. On closing these cocks and opening the upper one two balls are dropped into the tube, the first ball being adjusted to one degree

heavier than the water is intended to be maintained at in the boiler, the second ball one degree lighter; then close the upper cock, leaving the communication with the boiler open. Now, if the density of the water should increase beyond the standard adopted, the lower ball would rise, and if it should decrease the upper ball would sink. This is a very ingenious but rather delicate instrument, the use of which has now for many years been superseded by other contrivances. The simplest, though crudest, is one, it is believed, still extensively used in many places, and consists simply in a can or measure, sometimes detached from and sometimes attached to the boiler. This vessel is filled with water from the boiler at certain intervals for ascertaining the density; the water is allowed to cool down until a certain temperature is obtained and found by dipping a thermometer into it, and then the hydrometer, graduated to that temperature, is dipped in, which, by the degree of its immersion, indicates the specific gravity or density of the water. Such an instrument will, of course, fulfill the object of showing the density any time it may be required, but the operation is tedious and requires care, and handling such delicate glass instruments is not exactly the thing in rough weather, when the engineers have many parts of the machinery requiring their constant attention. The next step was the introductien of more practical and complete apparatus, the most commonly known of which is that called How's salinometer. The construction of this instrument will be seen from Plate III., Figs. 6 and 7. How's salinometer case contains a separate compartment for the hydrometer and thermometer, and it is easy enough at any time to let in the water from the boiler so as to fill the case, shutting off the communication with the boiler and blowing off the surplus water, if any; the density of the water when the ebullition has ceased can be read off. But this ebullition, resulting from the reduced pressure of the atmosphere to which the water in the salinometer case now becomes subjected, causes a quantity of hot water to be thrown out of the case, thus exposing the engineer to be scalded; the sudden rush of water from the boiler, if not properly checked by opening the cock very carefully, tends also to throw the hydrometer with great force upwards, causing the danger of breaking it; nevertheless, this instrument has been and is still extensively used.

A more complete salinometer than the preceding one is illustrated by Plate III., Fig. 8. This is the invention of Mr. Long, a chief engineer of the United States Navy. The objections to How's salinometer are obviated in this instrument by the addition of another separate tube. This latter contains a smaller internal tube by means of a cock communicating at the bottom with the water in the boiler while the top is closed, but having small openings near the upper extremity, through which the water can escape in the outer compartment of the long tube or vessel, the steam at the same time freely disengaging itself. The long casing communicates at the bottom with the salinometer casing, which is fitted with a thermometer and a hydrometer. By this arrangement the rush of water and the violent ebullitions are checked, and thus the density of the water can be observed without danger and in-

convenience. But a more convenient and less cumbersome apparatus is represented by Plate III., Figs. 1 and 2. This salinometer, the invention of Mr. Gamble, chief engineer of the steamer *City of Norwich*, has all the advantages of Long's, while the whole apparatus is contained in one piece, thus offering less obstruction, being more sightly and taking up less space in the engine room. This salinometer is now coming extensively into use, and is being manufactured by Messrs. Hayward, Tyler & Co., of Whitecross Street.

In Plate III., Figs. 3, 4, and 5 is shown an improved pattern of the same apparatus. The water is admitted, through the side entrance of the four-way cock, into the hollow of that cock, and from there, by opening the regulating screw of the jamb-valve, into the bent copper tube in the salinometer case. At the top of the bend is a hole for letting the steam freely escape. By passing through in this way the force of the water is broken, and it will now enter the larger tube containing the hydrometer quietly. That tube is cut open on one side, and a corresponding hole left in the casing, with a glass plate inserted in the same, shows the density of the water at any time. By the side of the hydrometer-tube is a cavity containing the thermometer, the indications of which can likewise be seen through a glass. An overflow-pipe carries the surplus water away. Closing the jamb-valve occasionally and then blowing through from the boiler enables the engineer to clear the supply-pipe from any sediment, and this is an important point. The next operation in starting the salinometer afresh, is to blow it through, which can be easily done by opening the jamb-valve and setting the handle of the four-way cock so that a line on the dial plate points straight through from the salinometer to the waste-pipe; this clears the salinometer and allows the water in the supply-pipe time to cool down before entering the salinometer. 200° Fahr. is the temperature the hydrometer is gauged to. By the regulating screw of the jamb-valve this can be easily and conveniently obtained as well as retained. Another great advantage in this practical little instrument, though it may not at first sight appear to amount to much, is the arrangement of the scales. The indications are given outside the brass face of the instrument where they can be read off instantly. In conclusion, there is no doubt that, after all, blowing off in the proper manner is the best means of preserving the boiler, that there cannot be given the engineer facility enough to do so, and that a salinometer possessing the advantages just described, which are fully borne out in practice, forms the best safeguard against the incrustation of marine boilers.

The Hydraulic Propeller.

From the London Mechanics' Magazine, April, 1866.

The attention of the scientific world has recently been directed to a practical illustration of a system of hydraulic propulsion which has been successfully worked out by Mr. N. W. Ruthven, of Blackwall, in a vessel called the *Nautilus*. In our last number, we briefly noticed

SALINOMETERS.

Fig 4.

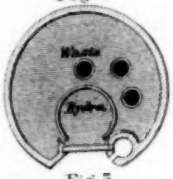


Fig 3.

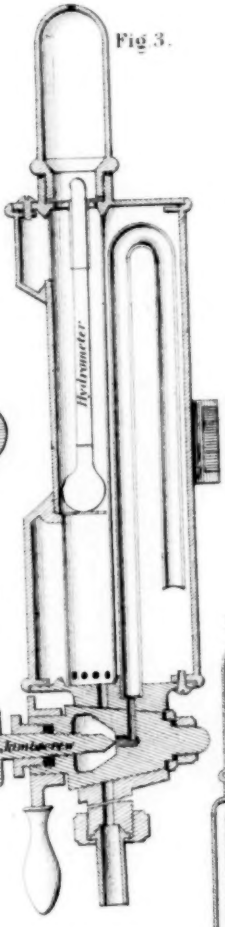


Fig 6

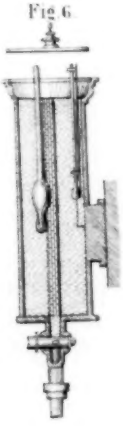


Fig 7

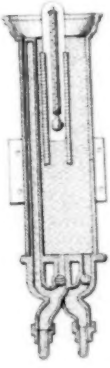


Fig 5.

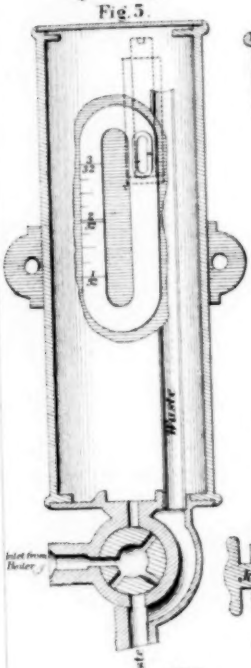


Fig 2.

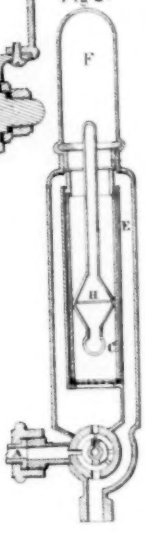


Fig 1.

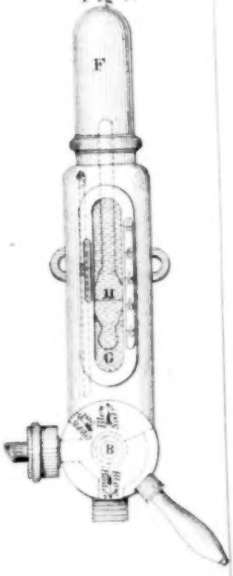
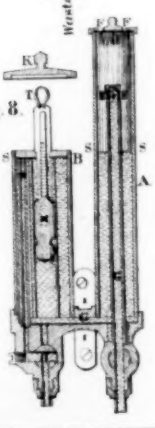


Fig 8.



a private trial of this new principle of motion as applied to the above vessel, and which was attended with highly successful results. No less satisfactory were those which accompanied a run made on Saturday last with the *Nautilus*, from London Bridge to Long Reach and back. We may premise that the vessel was built by Mr. Ruthven at the Orchard Yard, Blackwall, for the purpose of practically proving the advantages of this method of propulsion. Her hull resembles somewhat that of one of the *Citizen* boats; she is of the same length, but much broader and deeper, and fuller in the lines, so that in constructive outline the *Citizen* possesses a decided advantage. She is fitted with two steam engines, each of about 10 nominal horse power, by Mr. Smith, of Wells Street, Oxford Street, her cylinders being 17 inches with 2 feet stroke. Her boilers are of the ordinary type, and were made by Messrs. Camroux & Co., of Deptford. But the point to which our attention is chiefly to be directed is the propelling apparatus, which is based upon the principle of the turbine. It consists of the combination of a centrifugal pump of peculiar form with curved plates, by which the water is drawn into the vessel from beneath her and discharged in different directions. The reaction caused by its outflow drives the vessel in a direction opposite to that in which the water affects its exit. In the *Nautilus*, water is admitted through apertures in the bottom of the vessel into a water-tight compartment in which a horizontal turbine wheel, 7 feet in diameter, is placed, which is actuated from a vertical shaft connected with the two steam cylinders. The wheel is placed below the water-line of the vessel and thus is always immersed. A pipe is taken from the water-space to each side of the vessel, each pipe terminating with two delivery-nozzles, 10 inches in diameter, placed outside at right angles to the pipes, and which, consequently, point fore and aft the ship. A valve is fitted to each delivery-pipe at its junction with the nozzles, and which is actuated from a raised deck built over the engine house for the captain, who, by turning a valve, can eject the water from either nozzle singly, or from both at once. Such, in brief, is the simple apparatus with which the *Nautilus* is fitted, and which possesses palpable advantages over the ordinary methods of propulsion.

We are to examine into these advantages, inasmuch as the success of the *Nautilus* has been very marked, and also because the *Waterwitch*, an iron-cased gun vessel of 778 tons, and 167 horse power, is now being fitted with engines upon Mr. Ruthven's principle. In the first place, there will be no loss of power from slip as with the paddle-wheel or screw, so that with equal quantities of fuel greater power is obtained. In the next place, the engines give a uniform and continuous power, resulting in a smooth motion, so that, all things being equal, there is an absence of vibration, so detrimental to the vessel. Then we have no reaction on the engines from the motion of the vessel in a heavy sea, the propelling power remaining as efficient in a storm as in a calm. Hence the risk of damage to machinery is obviated, and on a long voyage a practical increase of speed or economy of fuel would result. The *Nautilus* is independent of her rudder, and can

be turned on her centre by the propeller alone without the helm and without steerage-way. The motive power is completely under the control of the commander by means of the valves, so that no communication with the engines is necessary for backing or turning. As applied to the *Water-witch*, and vessels of war in general, the hydraulic propeller offers still further advantages. The propelling power being situated within the vessel, the risks to paddles or screws from shot, fouling, or other accidents are avoided. Whatever the draft of water may be, the propeller will work effectively, so, as long as the vessel floats, she must be propelled. Provision is made for shutting off the regular supply of water from the canals, so that in the event of the ship being pierced with shot or springing a leak, the water from the leak is taken up instead for supplying the centrifugal pump. The water would thus be kept under and the vessel propelled at the same time, as with a 500 horse power engine about 1000 tons of water per minute could be discharged through the nozzles. There is a marked difference in the construction of vessels fitted with paddles or screws, and those propelled by hydraulic power. In the paddle-boat we have paddle-wheels and boxes, sponson beams, and the paddle-shaft; and in the screw vessel there is the screw-shaft, screw-tunnel, and the solid wrought iron double stern-post, so costly in large screw vessels, all of which are avoided with the hydraulic propeller. Here is simply a turbine wheel, water-chamber, and nozzles, the cost of constructing which need not exceed that of those parts in the paddles or screw which are dispensed with. These considerations point out that the important element of safety is present in a very marked degree in Mr. Ruthven's system, whilst the appearance of the vessel is much improved, as in the construction of the hull the lines of a perfect sailing ship can be maintained, the propellers in no way interfering with the efficiency of the vessel as such.

The invention of the hydraulic method of propulsion is not a thing of yesterday. Many attempts have been made at various times to accomplish the object, but all endeavors to adopt theory to practice proved futile until Mr. Ruthven, in 1839, invented an apparatus for doing so. A small vessel 9 feet long was constructed about that time, and later on, in 1844, a larger one 40 feet long, both being worked by steam power and fitted with Mr. Ruthven's propeller. These vessels attracted considerable attention at the time, and the Admiralty directed Mr. Murray, the present chief engineer of Portsmouth Dockyard, to experiment with the larger one. Although the results were highly favorable, and although Mr. Ruthven exerted himself to have the invention taken up, it was only a nine days wonder, the inventor's best efforts being unsuccessful. Still, however, he tenaciously clung to his idea of its practical adoption, and in 1849 a few further improvements were made which were subsequently introduced in a vessel about 30 feet long, which was placed on the Thames. It was not, however, until 1853 that the first vessel for commercial purposes was made. This was the *Albert*, which was built in Prussia by a Mr. Sydel, partly at the expense of the Prussian government, the engines and other

machinery being furnished by Mr. Ruthven. This vessel has been employed ever since running regularly on the Oder, where she has proved the complete success of the invention. But, for all this, Mr. Ruthven's patent expired before the principle could be commercially tested in England, so that, in 1863, the Privy Council, impressed with its merits by the practical evidence given, renewed the patent for ten years. This is the only instance on record of such a lengthened period being granted, and may not occur again. Having obtained a renewal of his patent, Mr. Ruthven again set to work to construct a vessel in which the system should be exemplified, and thus the *Nautilus* came into existence. Since the *Nautilus* was commenced the Admiralty have been induced to apply the hydraulic propeller to the *Water-witch*, now being built by the Thames Iron Works Company, and engined by Messrs. Dudgeon, of Millwall. The engines and hydraulic machinery have been designed by Mr. Ruthven, who is also superintending their construction. The vessel is expected to be ready in May next, and will afford an example of the working of the principle on an extended scale.

The trial made on Saturday last with the *Nautilus* was as satisfactory in its results as those which had preceded it. The *Nautilus* ran against the Iron Boat Company's vessel *Volunteer*, of 24 horse power, which she distanced without any apparent effort. That the *Volunteer* did her best was evident from her firing-up, but in order to see that all was fair, Mr. Steel, of the Machinery Department, remained on board of her during the run. As the *Water-witch* is being engined upon the same principle as the *Nautilus*, the Admiralty naturally manifested some anxiety upon the subject, and, although the trip on Saturday was not an official one, several government officials were present to observe and report upon the proceedings. Among these were Admiral Elliot, Mr. Murray, of the Portsmouth Dockyard, and Mr. Steel; Captain Englemere and several other practical officers of the Peninsular and Oriental Company were also present. As the trial was not an official one results of a general character only can at present be given, but when the official run is made we shall hope to lay before our readers the details of working. It may, therefore, be stated that, from the trials already made, it is found that, with the engines working smoothly and steadily, and up to their full speed of 85 revolutions, the *Nautilus* can maintain a speed of twelve miles an hour. On Saturday this vessel, fitted with engines of 20 horse power, certainly distanced the *Volunteer* with 24 horse power, thus proving, at any rate, the soundness of the principle of hydraulic propulsion. Although we must wait for the practical trial at the measured mile for exact results, we may fairly pronounce the trips which have been already made to be highly successful. Constructed on a model unusually full in the lines and with no extraordinary power, this vessel may be considered to afford a severe and reliable test of the principle she illustrates. The steering of the *Nautilus* is effected by a rudder of peculiar construction, which is also the invention of Mr. Ruthven, and applied, for the first time, to this vessel. It is of the usual breadth, but,

instead of being in one piece, it is divided into four parts and held together by joints or hinges. When put over, these parts, by a simple arrangement, form a concave surface to the action of the water, and the water thus deflected presses with great force upon the rudder, by which means the vessel is turned in about one-third the time usually required. The apparatus which actuates the rudder is another creation of Mr. Ruthven's genius, and consists of a working lever on a fixed pin at one end, and with a power applied at the other, but with a link about the middle of it connected with the end of the ship's tiller. The power in the *Nautilus* is a spiral spring, but any other available power can be applied, from a simple pulley and weight to a powerful hydraulic piston. Mr. Ruthven's object is to overcome a difficulty in moving the helms of ships, especially screw steamers, when going at high speeds. So he, by this apparatus, applies an extra amount of power to the tiller, which power can be so regulated as to assist the helmsman to the extent of the water-pressure on the rudder. The rudder is in effect held in a state of equilibrium, the helmsman being thus relieved of the labor of heaving over the helm, and leaving him simply the duty of guiding it. From its construction it will be seen that the apparatus has the further advantage of acting as a counterpoise, and thus prevents the sudden shock to the rudder and flying round of the wheel on the helm being righted or shifted. The apparatus is not necessarily an adjunct of Mr. Ruthven's rudder, and may be applied to any description of rudder. Upon the whole, then, we have to congratulate Mr. Ruthven upon the very successful result he has by dint of patience and perseverance at length achieved. Machinery more simple could not be conceived for the purpose; hence renewals and repairs can never form large items in the cost of maintenance. Judging from what has been done already in testing its efficiency, we may infer the hydraulic propeller is destined at length to assume a position of importance in the world of marine engineering.

The Cycloscope, for setting out Railway or other Curves without the aid of the Transit Theodolite. By Mr. H. Temple Humphreys.

From the London Mechanics' Magazine, June, 1866.

At a recent meeting of the Institution of Civil Engineers, Mr. H. Temple Humphreys, Assoc. Inst. C. E., exhibited and explained, with diagrams, an instrument called the Cycloscope, for setting out railway or other curves without the aid of the transit theodolite, &c. Externally it somewhat resembled a box-sextant. It was composed of two essential parts only, viz: two plane mirrors, one of which was silvered over the whole of its surface, and the other over one-half of its surface. By a law of physical optics, which was called either combined or successive reflexions, a series of images would be formed in the half mirror, which were rendered available to set out any curve of any given radius by applying the eye to an eye-hole in the back of the whole mirror, and, at the same time, setting the two mirrors at an angle to one an-

other equal to the required tangential angle. Then the several successive reflected images of a ranging-rod, for instance, were seen to lie upon the circumference of a mathematically true circle. The curve was then readily set out in the field by simply placing other ranging-rods in line with these several images. This could be done by looking through the unsilvered half of the half mirror, and planting the rods opposite to and overlapping the successive reflexions. No error could arise in the manipulation, and the whole process of setting out a true curve was shortened and simplified. After setting the mirrors to the requisite tangential angle, no further adjustment or support was needed than could be afforded by the top of a ranging-rod placed at the commencement of the curve, and shifted occasionally to any stake on the curve that the limits of distinct vision might require.

Cantor Lectures.—On Submarine Telegraphy. By FLEEMING JENKIN, Esq., C.E., F.R.S.

From the London Journal of the Society of Arts, No. 689.

LECTURE I.

The Insulated Conductor and its Properties.—The lecturer stated, that in the lectures he was about to deliver he should aim rather at spreading more widely the knowledge possessed by those practically acquainted with submarine telegraphy, than at announcing the latest discoveries or most novel theories.

Terms used—Conductor, Insulator, Battery, Earth, Circuit, Current.—Some elementary explanations were given with the view of explaining these terms. The action of a current on a magnetic needle, the simplest form of galvanometer and electro-magnet, were shown, with their application to practical telegraphy. The two sources of failure, viz: want of continuity in the conductor, and want of insulation forming a short circuit, were explained. The reflecting galvanometer was exhibited as a means of indicating a feeble current.

The following is a more detailed abstract of the rest of the lecture:

2. *Component Parts of Submarine Cable.*—These are—1st, the conducting wire, generally formed of copper; 2d, the insulator, surrounding the conductor, generally gutta-percha or india rubber; 3d, the outer covering, intended to give strength, and generally formed of a hempen serving, surrounded by iron wires, laid as in a rope round and round the core.

3. *Conductor.*—(*a.*) *Mechanical Properties.*—The conductor is almost universally made of copper, but a solid copper wire is apt to be brittle, breaking after being bent a few times. Interruptions occurred from this cause in early cables. This defect is wholly removed by the use of a strand of several wires, generally three or seven. The tensile strength of copper wire is in some books given as 60,000 lbs. per square inch. That used for submarine cables, being selected for electrical rather than mechanical qualities, will only bear from 35,000 lbs. to 39,000 lbs. per square inch. Copper stretches so much (10, 11, 12, or 15 per cent.) before breaking, that its full strength can

seldom be made use of. This extensibility is, as will be seen, a very valuable property, preventing the interruption of the circuit until the strengthening part of the cable be fairly broken. The following are convenient approximate formulas: A copper strand will bear $1\frac{1}{2}$ lbs. per pound weight per knot before breaking. It will stretch 1 per cent. with 1 lb., and will not stretch at all with 0·75 lb. per pound per knot. Thus a strand weighing 300 lbs. per knot will bearly support 450 lbs., will stretch 1 per cent. with 300 lbs., and will not stretch at all with 225 lbs. The weight of copper in lbs. per knot can be calculated from the diameter d in inches by the use of the following constants: Weight = 18,500 d^2 for solid wire, or 15,100 d^2 for strand. The joint of the conductor is made with great care. A scarf-joint is made by soldering together two filed and fitted ends. This joint is wrapped round with fine copper wire to give it strength, and solder is again run round this wire. A second wrapping of fine copper is then applied, and left without solder. The joint is necessarily less extensible than the rest of the strand. If forcibly torn asunder, the last wrapping of copper maintains the electrical connexion, being simply pulled out like a spiral spring. No interruption from breakage at joints has ever occurred since this system was adopted.

(*b.*) *General Electrical Properties.*—Copper is what is called a good conductor, offering small resistance to the passage of the electric current; that is to say, a much less powerful current would be sent by any given battery through a long iron or lead wire than through a copper wire of equal length and diameter. Table I. gives the relative electrical resistance of several substances compiled from Dr. Matthiessen's experiments. The lower the number the better the conductor.

TABLE I.—*Relative resistance of materials at 0° C. Wires of equal length and diameter.*

PART I.—CONDUCTORS.

Silver, hard	1·00
Copper "	1·00
Gold "	1·28
Iron	5·94
Tin	8·09
Lead	12·02
Brass	4·50
Gold silver alloy	6·65
German silver	12·82
Platinum silver alloy	14·93
Mercury	58·15

PART II.—INSULATORS.

Gutta-percha at 75° Fahrenheit 60,000,000,000,000,000,000	or 6×10^{19}
Glass not less than 600,000,000,000,000,000,000,000,000	or 6×10^{26}

Conduction takes place through the mass, and not along the surface of the wire. A strand and solid wire of equal weights are equally good conductors, but owing to what is termed lateral induction, to be hereafter explained, the strand is at a slight disadvantage for rapid speaking through long submarine cables. Messrs. Bright & Clark,

to avoid this defect, used in the Persian Gulf cable a segmental strand, built up of six wires fitting one another, and drawn through a tube. They hoped thus to combine the advantages of the strand with those of the solid wire. Mr. Thomas Allan surrounds his copper conductor with fine steel wires, to give strength and avoid the use of heavy external protection. In a sample given to the lecturer, the resistance of the conductor so formed was about 30 per cent. more than that of a simple copper conductor of equal weight. Taking induction into account, Mr. Allan's cable would be about 50 per cent. inferior in speaking power to a cable with simple copper conductor of equal weight, and covered with an equal amount of insulating material. This inferiority is not a fatal defect if the cost of the outer protection is avoided. The general merits or defects of this plan will be spoken of in a future lecture. Although the danger of decay where iron and copper meet is known, Mr. Allan's proposal deserves serious consideration.

(*c.*) *Chemical Properties of Copper Wire.*—A current flowing from the copper end or pole of the battery through a hole in the insulator to the sea, causes the formation of chloride of copper, a soluble salt. The copper is thus gradually eaten away, until metallic continuity is interrupted, and the cable ceases to transmit messages. The current from the zinc-pole does not produce this effect, but only a deposit of soda in the fault, which, however then allows a greater leakage, tending to enlarge the hole in the gutta-percha. Mr. C. F. Varley has proposed to twist up a fine platinum wire with the copper strand of long cables. This wire would maintain the communication at any point where the copper might be eaten away.

4. *Insulator.*—(*a.*) *Gutta-percha and Chatterton's Compound.*—Gutta-percha is pressed out, while warm and plastic, through a die round the conductor. Several successive coatings or tubes are thus applied, till the desired thickness is obtained. The first coating is attached to the strand by a substance known as Chatterton's compound, which is also used between each layer of gutta-percha, and between the separate wires of the strand, to prevent the percolation of water along the interstices, in case any part of the copper should be accidently immersed in water.

(*b.*) *Mechanical Properties.*—Gutta-percha has considerable tensile strength, bearing about 3500 lbs. per square inch of section, but, owing to its great extensibility, it does not add more than about one-third of its whole strength to the copper strand. Roughly, it may be said to add in small wires 20 per cent., and in larger cases 30, 40, or even 50 per cent. to the strength of the copper strand. It will stretch 50 or 60 per cent. or more without breaking, but almost always fails as soon as the copper inside gives way. It will bear ill-usage, such as knotting, squeezing, or stretching, without injury, but can be pierced with a sharp instrument, or cut by a knife, without much difficulty. Uniform pressure, such as it sustains under water, improves its electrical qualities, augmenting its insulation resistance, according to Mr. Siemens' experiments, about 60 per cent., at 24° C., for every ton pressure per square inch, corresponding nearly to 1000 fathoms depth

of water. It becomes soft at about 100° Fahrenheit, and should, after manufacture, never be heated beyond 90°. The joints required are made by heating the two ends of the covered conductors after the copper is joined, and applying by hand successive coatings of warmed and plastic gutta-percha. The separate layers of gutta-percha are also cemented by Chatterton's compound. Thus the joint is, when sound, very similar to the rest of the core. Extreme cleanliness and much skill are required in making these joints. Some years since the joints frequently failed, not always when just made, but after some months, becoming hard and brittle, and shrinking so as to leave a gap between the old and new materials. The process is now thoroughly understood, and is a safe one in skilled hands, but in skilled hands only.

(*c.*) *India Rubber.*—This material is applied in many ways. Most commonly tapes of masticated or bottle rubber are wrapped round and round the conductor until the required thickness is reached. At first these tapes were, as it might be termed, gummed together with solvents, but these caused decay, and have been abandoned. Heat is now the common agent for effecting the adhesion. Mr. Siemens, who applied his tapes longitudinally, like two long half-tubes, used simple pressure to join the two halves together. He employed most ingenious machinery to cut the tapes the instant before they were applied to the copper, as the material only reunites if quite freshly cut. Several successive coatings could be applied in this way at one operation. Some manufacturers considered that none of these methods were fully successful, and vulcanized the india rubber, converting it into various materials of different degrees of flexibility, according to the process employed. This material was also criticised, and Mr. Hooper has covered conductors with pure india rubber next the copper, followed by a coating of oxide of zinc and rubber, and enclosed by a vulcanized jacket. In the process of baking the core to vulcanize the jacket, a little sulphur penetrates the india rubber, and the whole mass becomes remarkably compact and durable. Mr. Hooper heats the core to 250° Fahrenheit, and bakes it for four hours. The mechanical properties of these different materials vary greatly. They are all, however, very extensible, and do not add sensibly to the tensile strength of the conductor. They will bear considerable ill-usage, but are mostly softer than gutta-percha, and the pure rubber will not bear continued pressure, even by a blunt surface, but gradually yields. The joints in each form are now made so as to imitate, as far as possible, the main core. Mr. Hooper bakes his joints two hours in a steam-jacket.

(*d.*) *Chemical Properties and Permanency.*—When dry and exposed to light, gutta-percha becomes dry and brittle, losing all its valuable qualities, and is said to be oxidized. Under the same circumstances the various forms of india rubber decay in various ways. Some become treacly, some brittle, some almost friable. Mr. Hooper's hard-covered seems to last best of all in air. When in water gutta-percha is, so far as fifteen years experience can show, absolutely permanent. Many thousands of miles have been laid down, and many hundreds of miles picked up, after lying in the sea in various parts of the world,

in deep and shallow waters, for many years, and not one single yard of material has been found which had, under those circumstances, decayed or lost its insulating properties. The importance of this fact cannot be over-estimated. The experience as to india rubber is the very opposite to this. Little has been employed, and a great deal of that little has been found to decay, so as to be utterly useless. No doubt improvements are continually introduced, and possibly some of the forms now made may answer better, but till the subject is more thoroughly understood it would be lost time to reproduce all the theories by which the various failures are explained. Out of five specimens supplied lately to the Indian government, one only (Mr. Hooper's) proved durable even for a year. The lecturer's own experience confirmed this experiment. It must, in justice, be said, that considerable lengths of india rubber covered wire are successfully used on land, supplied by Messrs. Silver and their descendant, the India Rubber and Gutta-percha Telegraph Construction Company, and by Messrs. Wells & Hall. The Indian government has ordered about 100 miles of wire covered by Mr. Hooper's material, which will, therefore, now be subjected to a thorough practical test. India rubber stands heat much better than gutta-percha.

(*e.*) *General Electrical Properties.*—Gutta-percha is a very good insulator. All insulators conduct a little, but the figure written after gutta-percha in Table I. will show the relative resistance to conduction with equal bulks of copper and gutta-percha. A better idea of the vastness of the number will be obtained by observing that light would take a century to travel through the number of feet which that number would express. The practical result of this degree of insulation with the Atlantic core is that more than 99½ per cent. of the current leaving England would reach America if the cable were but laid. Any improvement in insulation will, therefore, only go to diminish this half per cent. loss, in itself of no consequence whatever. India rubber has a higher resistance still. The chief advantage to be obtained from this high resistance is the facility it gives for detecting faults. India rubber is, however, superior to gutta-percha in another electrical property, called its inductive capacity. More words per minute, in the proportion of 4 to 3, at least could be sent through an Atlantic or other long cable insulated with india rubber, than if insulated with gutta-percha, the weight of insulator and conductor remaining the same. This point will be more definitely treated of hereafter.

(*f.*) *Absorption of Water.*—Mr. Fairbairn long since stated the superiority of gutta-percha to india rubber for deep sea cables, owing to the comparatively small quantity of water which it absorbs. Probably the newer forms of india rubber may have improved in this respect, but Mr. Siemens found that pure india rubber absorbed 25 per cent., vulcanized rubber 10 per cent., and gutta-percha 1½ per cent. of their weight in pure water. These quantities were reduced to 3, 2·9, and 1 per cent., respectively, in salt water. The absorption continued for 300 days. It was 8 times greater for india rubber at 120° of Fahrenheit than at 39°, but for gutta-percha it was only doubled

by the rise in temperature. Mr. Siemens considered that pressure affected the absorption very little. The amount absorbed by gutta-percha in no way damages it. This is proved by thousands of miles of submerged cables; for instance, the tests of the Malta Alexandria cable, laid four years since, under Mr. Forde's superintendence, by Messrs. Glass & Elliott. Part of this cable supports about half a ton per square inch pressure.

TABLE H.

	No stretch.	One per cent. stretch.	Breaking strain.
	lbs.	lbs.	lbs.
Atlantic core	340	414	660
No. 14 copper covered to No. 1, 107 lbs. copper, 166 lbs. gutta-percha	134	162	218
No. 16 copper covered to No. 4, 73 lbs. copper, 93 lbs. gutta-percha	100	120	150

TABLE III.—*Dimensions of cores of important cables.*

Name of Cable.	Copper conductor.		Gutta-percha.		Approximate ratio $\frac{D}{d}$.	Log $\frac{D}{d}$.
	Total weight in lbs. per knot.	Total diameter of conductor = d.	Weight in lbs. per knot.	Diameter in inches = D.		
Red Sea cable	180	0·105	212	0·34	3·4	1·224
Malta, Alexandria, standard	400	0·162	400	0·457	2·95	1·082
Persian Gulf	225	0·109	275	0·38	3·48	1·249
First Atlantic	107	0·083	260	0·38	4·8	1·57
Second Atlantic	300	0·144	400	0·464	3·28	1·19
England and Holland	143	0·095	223	0·34	3·47	1·244
Toulon and Algiers	107	0·083	223	0·34	4·26	1·45
Varna, Balaclava	73	0·062	166	0·3	4·84	1·58

5. *Mechanical Properties of Completed Core.*—Few persons are aware of the great strength of the common gutta-percha covered wire. An experiment was shown by the lecturer, in which 5 cwt. was hung from the slender looking core of the new Atlantic cable. It stretched some 10 per cent. under this weight, and was then taken down, knotted, squeezed, and cut open, when the copper conductor appeared quite undisturbed in the centre of the gutta-percha, which exhibited no trace of injury. Before the application of Chatterton's compound,

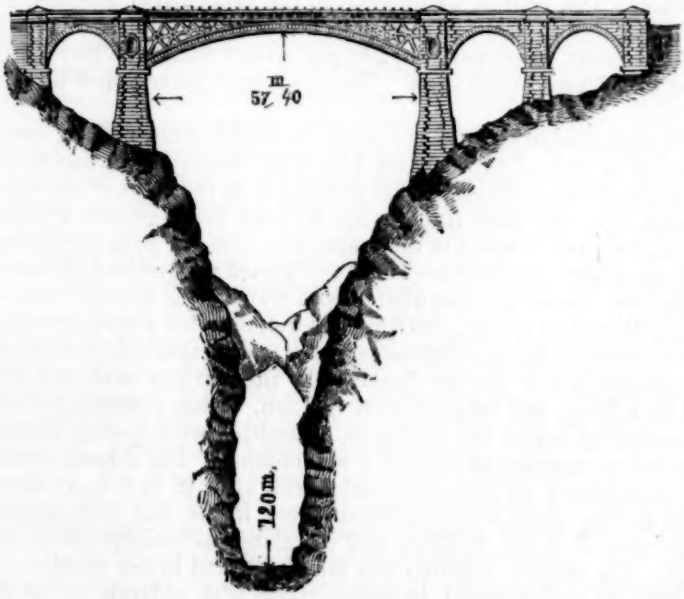
the wire was liable to start out of the cable after it had been stretched and cut, or softened, owing to the unequal elasticity of copper and gutta-percha, but with Chatterton's compound considerable force must be used to drag out the copper wire, even when the core has been stretched and is cut open. Table II. shows the strains which various wires can support.

Table III. gives the dimensions of the cores in some of the most important cables laid. It is noteworthy that 300 miles of the very smallest core practically in use, laid without any outer protection whatever, maintained our connexion with the army for nine months during the Crimean war.

(To be continued.)

Cast Iron Bridge near Constantine, (Algiers.)

We copy the design of a very graceful cast iron bridge, thrown by a French engineer, M. Martin, over a deep and precipitous ravine, near Constantine, (Algiers.) The span of the main arch is 57·4 metres (188 feet) in span, and the depth from the roadway to the bottom of the ravine is 120 metres, (393 feet.) The only novelty of any interest about the construction was the method taken to support the centering of the



arch. As the depth was so great, and the bottom occupied by a torrent liable to sudden and destructive floods, the attempt to build up a support from below would have been both expensive and hazardous. The engineer, therefore, threw four cables across the chasm, two on

each side of his proposed bridge, from which he supported a platform, on which the arch centering was built. The wooden centres, when finished, found their support at their abutments, and the suspension bridge was retained only for the service of the work, and the iron arch-stones were never permitted to rest upon it.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

The Working Processes for the Reduction of the Gray Copper (Tetrahedrite) Ores at Stefanshütte, in the Comitat (County) of Zips, in Hungary. By J. L. KLEINSCHMIDT.

(Continued from page 132.)

In a second trial, I precipitated, after the separation of the copper by hydrosulphuric acid, oxidation of the fluid, etc., the ferric oxide, partly by carbonate of soda, and then, after filtering, the rest by soda lye. The precipitate thus obtained was melted with metallic arsenic, cyanide of potassium, and black flux in a crucible, (tute,) but no globule was obtained. Iron and copper were separated in the nitric acid solution by ammonia in the usual way. The ferric oxide was dissolved a second time in hydrochloric acid, and to the solution ammonia added in excess. The copper, by titration in the ammoniacal solution, gave 25·95 per cent.; add to these 0·98 per cent. from the SbO_4, we get 26·93 per cent. of copper. 0·0200 grs. gave 0·0027 grs. ferric oxide, equal to 9·1 per cent of iron. The silver was ascertained by cupellation.

The iron pyrites ores (kiese) which are added to the melting contain lead, but in several experiments I have not succeeded in finding it in the crude speiss, (rohspeise,) but I found it in the slags of the copper refining, (Spleissabzüge;) therefore the lead has a greater affinity to the sulphur, and remains in the matte, and does not go to the speiss.

Crude Matte, (Rohlech.)—This was digested with nitric acid until all sulphur was dissolved, then diluted with water. The residue, after settling, gathered on a filter, and while yet wet, digested with concentrated muriatic acid, to which, afterwards, water and tartaric acid were added. The residue, which was not dissolved by the muriatic acid, was gathered on a filter, and weighed after ignition. This, consisting of slag, was examined before the blow-pipe, by melting with cyanide of potassium, but no reaction of antimony was obtained. The diluted solution was precipitated by hydrosulphuric acid, after it had been warmed to the boiling point with sulphurous acid, in the last determination the precipitate dried, weighed, and calculated as tersulphide of antimony. The original solution was measured, and in one portion of it the sulphur determinated by precipitation with chloride of barium, and the precipitate several times boiled with muriatic acid. Iron and copper were determinated as mentioned above, the silver by cupellation.

Crude Slag, (Rohschlacke.)—This was decomposed by melting with

carbonate of soda and chlorate of potash in a platinum crucible. It was found that nothing of the crucible was dissolved by the operation, if in the separation of the melted mass from the crucible no acid was employed. The mass was supersaturated by hydrochloric acid, evaporated to dryness, and in general proceeded as in the analysis of silicates. It was not possible to decompose the slag perfectly by digestion with hydrochloric and some nitric acids. At first I made use of this method, because I feared the platinum crucible would be injured by the fusion with chlorate of potash, but it was necessary to decompose the resulting silicic acid once more by fusion with carbonate of potash. It is not possible to prepare the slag by washing, because most of the interspersed matte would, on account of its greater specific gravity, remain at the bottom. The fluid, separated from the silicic acid, was boiled with sulphurous acid, to reduce the ferric oxide, and then precipitated by hydrosulphuric acid, the precipitate gathered on a weighed filter, after weighing burnt, and then dissolved either in nitric acid, and the ammoniacal solution titrated by cyanide of potassium, or, after roasting, to remove the sulphur, melted with cyanide of potassium, carbonate of soda, and some borax, and the copper globule rendered pure before the blow-pipe by melting it with some borax-glass. A trace of oxide of cobalt added to the melting mass, acts, in the refining of the copper, as indicator, and it can be easily evaded, that any trace of copper goes into the slag. I found the latter method for slags more reliable than the wet way, where it is difficult to know if there are not traces of copper retained with the antimonious acid, although, by the solution of the hydrosulphuric acid precipitates, I obtained always the latter perfectly white. The copper is then calculated as sulphide of copper, and the antimony from the difference. The other substances were determinated in the usual way.

Roasting of the Matte.—The mattes are roasted in pieces of about 2 inches diameter, in oblong heaps, in the open air. There are brought in one heap 1000 to 1500 cwt. of matte, and in the first roasting, by 12 feet width, they are made of such a length that the matte is 1½ feet thick on the thin layer of wood. At every succeeding fire the heap is made shorter and higher, more and more wood is taken, and from the fifth or seventh fire, accordingly as the roasting has advanced, a layer of charcoal is added to the upper part of it.

In this manner 10 to 13 fires are given, and the mattes are considered only then as being well roasted, if they form a black, porous, light mass, which may contain metallic copper, but no undecomposed matte. In the last fire the roast forms a quadratic pyramid of 10 to 12 feet length of the sides, and 8 to 9 feet high. Lately it was the intention to try the roasting in covered stadeln, (roasting places surrounded by a wall.) My experience in Mexico and Ducktown, Polk Co., Tenn., have convinced me, that the roasting of the mattes and ores, where it is done as a preparation for the melting in shaft furnaces, and where it is not necessary to condense volatile products, is done best in the open air.

Melting of Roasted Matte, (*Rostdurchstechen.*)—The well-roasted

mattes are mixed with 20 per cent. of raw quartzy ores, containing from 3 to 4 per cent. of copper. By this melting are obtained: Black *copper*, with 80 to 84 per cent. of copper, and 3 to 4 ounces of silver; upper matte, (*oberlech*,) with 50 to 60 per cent. of copper, and 1 to 2½ ounces of silver and slags. The furnace used for this purpose measures from the tuyeres to the mouth only 8 feet. The other dimensions are the same as those of the furnaces for crude melting, (rohöfen,) but there are no boshes. The furnace has two tap-holes, the one for the black copper on the side, the other 10 inches above the first, in the middle, for the matte. From the lower tap-hole an iron kennel leads to a water-basin, in which the tapped metal runs, and hereby becomes granulated. The matte runs by the tapping to a sump pool, as in the crude melting; first the matte is tapped and then the black copper; the consumption of roasted matte is about 10 tons in 24 hours.

The produced black coppers (schwarz-kupfer) have a fine grained fracture, and almost silver-white color, and form bluish, clustered, blistered masses and grains; and because they are to be stamped and reduced to powder, a certain amount of antimony is needed, to give them the necessary brittleness; if they contain more than 87 per cent. of copper, they can only with difficulty be stamped and ground.

The composition of Phönixhütte oberlech, (matte obtained by the melting for black copper at the Phönixhütte,)—

S	22·25
Cu	60·00
Fe	16·52
Sb	0·10
Slag	1·50
	100·37

Schwarz-kupferschlacke (Black Copper Slag of the Stefanshütte.)

SiO_3	31·70
FeO	62·33
Fe	3·00
Cu	0·87
S	1·23
CaO	0·44
MgO	0·10
	99·67

Schwarz-kupfer der Stefanshütte, (Black Copper of the Stefanshütte.)

	Produced May, 1864.	Produced Oct., 1864.
Cu	83·10	86·50
Fe	2·80	3·50
Sb	13·35	8·46–8·03
S	1·05	1·05
Ag	0·25 (4 oz.)	0·25 (4 oz.)
Co. and Ni	traces.	traces.
	100·55	99·76

The upper mattes, (oberlechs,) differ always in their amount of copper. They were not analyzed, but in their weekly assays they show almost the same per centage of copper as those of the Phönixhütte, from which, except in their yield of silver, they cannot differ much. Like these they contain fine threads of metallic copper in the pores. Their amount of sulphur, therefore, is less than that of the crude matte, (rohlechs.) The oberlech (upper matte) are added to the roasts of the crude mattes in the fifth fire.

The slag of the melting for black copper, (rostchlacke;) it was already above mentioned that it is added to the crude melting as flux, where likewise is given the composition of it. It flows over the slag drift; therefore it contains less copper than that of the Phönixhütte, where black copper, matte, and slag are tapped together. It never contains undissolved pieces of quartz, proving that the quartz is easily turned into slags, if only the necessary bases are present, and the furnace is constructed in such a way that the ferrous oxide goes into the slag, instead of becoming reduced. With the produced speiss and the black copper, (schwarz-kupfer,) the melting work balances its accounts. The products are weighed, assayed, and given over to the amalgamation works.

Amalgamation of the Black Copper, (*Schwarz-kupfer Amalgamation.*)—The granulated black coppers are stamped beneath iron stampers, then ground, first between iron mill-stones, then between stones of granite. The powder must be as fine as the finest flour. After having been mixed with 10 per cent. of common salt, it is placed upon the upper hearth of a reverberatory furnace of the known Hungarian construction, as they are now in use in Saxony, the Hartz, &c. On this it remains for five hours, during which time it must be constantly stirred. It is then lowered down to the lower hearth by an opening which connects both. The fire in the first two hours is only slow, so that in the upper furnace, which has no direct fire, the charge requires at least two hours before getting dark red-hot, in which low state of temperature it must be kept during the next three hours remaining there. On the lower hearth the fire for the first two hours must be so slow that the glowing is visible only at night, and then the heat is, in the following two hours, increased to bright red heat, which, in the fourth hour, comes near to white heat. In the last (fifth) hour, the fire is moderated so as to draw out the mass at dark red heat. In the upper as well as in the lower furnace, the charge must be stirred and turned continually, and although the black coppers are not very easily rendered fluid, there is attention required, particularly in the upper furnace, that no lumps are formed and masses adhering to the bottom of the furnace. It is not enough to have converted the silver perfectly in AgCl, to which a much less degree of heat would be sufficient, but it is necessary to decompose so much as possible the sulphuric and antimonial salts. If this is not done it will result in a great loss of quicksilver, and the residues remain too rich in silver.

The outdrawn powder, after cooling, is separated from the lumps, which may have formed, by sifting. The latter are added to the

roasting of the next charge in the upper furnace without previous grinding. In this state they show themselves more profitable, because they loosen the black copper powder, and prevent that it accumulates. The sifted powder is then ground very finely, and given into the amalgamation casks in quantities of 12 to 15 cwt., according to their size, and mixed with such a quantity of already used lye from the reservoir (see below) warmed to 86° to 122° Fahr., (in winter it wants to be warmer than in summer,) that the quickmud (quickbrei) thus formed has the consistency of thin honey.

In filling the casks, which contain already 100 lbs. of copper balls, 10 to 15 lbs. of common salt are added to strengthen the lye. Generally some quicklime is added to it, to saturate the acid, and to decompose partly the metallic salts, which in most cases are in too great a quantity in the lye and the roasted black copper. Then the casks are slowly turned around their axes for about half an hour, when a trial is made, as follows: Some of the quickmud (quickbrei) is put in a glass cylinder, diluted with water, well mixed, and then put away for one hour. The powder must settle in this time perfectly to the bottom, and the supernatant lye be clear and almost without color. This not being the case, the quickmud contains free acid, and more lime or ashes must be added. When the quickmud is found to be in the right condition, 400 lbs. of quicksilver are added, and then the casks moved around their axes for 18 hours. After this time a sample is assayed by cupellation. If in 100 lbs. of the residues only $\frac{1}{16}$ of one ounce of silver is found, the cask is emptied, otherwise the operation is continued. The mercury containing the silver is taken from the cask, filtered through a cotton flannel bag, the more solid amalgam which remains pressed by a hydraulic press to separate as much as possible the free quicksilver, and then distilled in a cast iron retort, whereby the quicksilver is reobtained. The pressed amalgam contains only 18 per cent. of silver. After the distillation of the quicksilver, the silver is melted in the same retort, scummed, and then cast into ingots. It contains only 2 to 3 denär $= \frac{1}{16}$ to $\frac{3}{32}$ ounce of copper in the mark, or 8 ounces. After the separation of the mercury the cask is emptied, the powders separated from the copper balls by a sieve, washed several times, and when they have settled and got consistent, they are taken out and brought to the melting furnace. The lye, which is used again in filling the casks, is put in large reservoirs, in which it is kept for further use.

Melting of the Residues of the Black Copper Amalgamation, (Rückstand-schmelzen.)—The residues, when brought to the furnace, contain 16 per cent. of water. They are mixed with 20 to 50 per cent., as they are in store, of not fully roasted "gelf-lechs," (matte containing no silver,) of latter processes, and 10 to 15 per cent. of poor quartzy ores, together with 20 to 30 per cent. of slags of the melting of roasted matte for argentiferous black copper, and melted in one of the same furnaces, which are used for the crude melting, (rohschmelzen.) In building the melting works a stamp mill with drying stove had been provided, to mix the residues with clay or quicklime, but

this was not continued very long, and the residues are now given to the furnace, as they are, with 16 per cent. of water. In consequence of the moisture, and the pulverulent state of the mass, the melting proceeds very slowly. Formerly some pyrites were added instead of the partly roasted matte, but thereby a very inferior copper was produced. The products of this melting are gelfkupfer, (copper free of silver.) oberlech, (upper matte,) and slag.

The composition of them is:

Rückstand Schwarz-kupfer. (*Black Copper produced from the Residues of the Amalgamation of Black Copper of May*, 1864.*)

Cu	85·90
Fe	4·20
S	0·55
Sb	9·35
	100·00

Rückstand Schwarz-kupfer Schlacke, (*Slag from the Melting of the Black Copper Residues after their Amalgamation, May*, 1864.)

SiO_2	38·20
FiO	57·60
S	1·47
Cu	0·50
Sb	0·30
CaO	1·34
MgO	0·38
	99·79

The black copper of this melting has more the aspect of black coppers as they are produced on other melting works. It is very difficult to break it to pieces, fracture hackly, color white, here and there changing into yellow and gray. These black coppers almost always contain iron, from which sometimes only traces are to be found in those which are argentiferous. When free from iron, the copper may go into the slag, although the yet considerable amount of antimony prevents this to some degree. The slag stands, in respect to the amount of silicic acid between roh and rostslag; getting cold in thin pieces it is almost glassy, in thick pieces the fracture is smooth, pillar-like almost, color bluish-black, runs well on the slag drift, and contains very few grains of matte.

The oberlechs (upper matte) were not analyzed. They contain in their cavities a great deal of copper in form of threads. Their per centage amounts to 50 to 60 per cent. They are roasted with 4 to 7 fires, and given to the next melting of the residues of the black copper amalgamation. The melting of these residues is very troublesome for the workman on the mouth of the furnace, because there is a continuous volatilization of terchloride of antimony. The whole space before the mouth of the furnace (schichtenraum) is very often full of a dense white smoke, which seriously affects the lungs, and causes vomiting. When the vapors escaping at the mouth of the furnace do not burn with flame (dark mouth) the smoke is still more intolerable. The slags are thrown away, but the black coppers come to the

* Ni, trace. Co could not be found. Sb from the loss.

Spleissen.—This is done in a spleissofen (spleiss furnace, reverberatory furnace) of the Hungarian construction. In the beginning the melting was done with generator gases in furnaces constructed in the manner of an English copper-melting furnace, but so many difficulties occurred, and, at the same time, the smelting was so expensive, that the old method was taken up again. The hearth of the spleiss furnace is formed of stamped talcose slate, mixed with yellow loam. When yet damp it is beaten in and covered with pine brushes, whereupon the black copper is laid. A charge consists of 30 to 50 cwt., and the pieces are arranged in such a way that they offer an ample passage to the flame. The warming lasts 48 hours; then follow 10 to 12 hours of slow firing, in which the copper glows only dark red, after which time it commences to melt together. Until this time no wind is given, but now the same is turned on, and the fire increased to melt the slag. This lasts 2 to 3 hours. The slag melted, the copper begins to boil, then the wind is moderated, and the slag drawn from the copper by a wet piece of wood fastened to an iron bar. This slag, first drawing, (1ter abzug,) is very refractory, has a dark color, and can be drawn only with difficulty from the furnace. It consists mostly of the earthy masses, which adhere to the spleiss chips, which are returned into the furnace. As soon as the slag is drawn, and the copper appears with a bright surface, a dense smoke emanates from it, and the copper is now in the state which is called the "schwefeln," (emanation of sulphur,) sulphurous acid emanates, the wind is quite turned off, and the fire moderated, so that the copper for about two hours is quietly left alone. During this time copper, in form of a fine dust, is thrown up constantly from the melted metal. As long as this fine dust is visible, no wind can be given, because by doing so copper dust would be blown out of the furnace. When the copper begins to become quiet, some wind and more fire is given, and both are increased for about 8 to 10 hours until the copper is tapped. In this period every hour the slag must be drawn. As soon as this is done a great deal of antimonial smoke escapes. During the last hour, when by an increased wind the fire must be very strong, the slags are drawn every quarter of an hour. As soon as no white smoke emanates from the copper, it is stirred up with green birch poles, (poled,) and wet pieces of wood are made to swim on the copper. All these coppers must be driven very high to produce a good copper by refining lastly in an open hearth, (gussherd.) The quickly cooled proof (gaarspan) on the interior side must be of a pink color without dark spots, the outside dark brown, the edge (grat) thick and rounded, not thin and sharp. If all these tests are found perfect, the wind is turned off, and the copper is tapped. It flows by two tapholes in the warmed vortiegel (pits in the form of crucibles, cut in a mixture of loam and charcoal, which is stamped in a space before the tapholes, inclosed by iron plates,) then water is thrown at the surface of it. The cold disks or cakes (spleissen) are taken off by a fork (forkel) and thrown into cold water. The cakes thus obtained are sold only in small quantity as such, but most of them as refined into hammered plates, (hammergaare platten.) To

that end they are melted in an open hearth, made from stamped talcose slate and some loam, and as soon as the copper is refined (gaar) it is cast by a ladle into moulds. Yet red-hot are these brought beneath a water hammer, and are forged until their thickness is only two-thirds of the original. When the copper in the hearth smokes, the hammer-master drives it above the refining point, and reduces it again by stirring it with a wooden pole (poling), and let it then come to the right point again, and repeats the operation if necessary.

The "hammergaare rückstand-kupfer" (refined copper from the residues of the black copper amalgamation) thus produced has the composition:

Cu	98·99
Sb	1·01
Ni	trace.
	100·00

This can be hammered without getting edge-cracks, and can be rolled to thin plates. There is a great demand for it in Austria, and it is preferred to many other brands.

The slag of this process (gaarschlacke) contains, separated from the grains of metallic copper dispersed in it, of suboxide of copper, 12 per cent. = 10·5 per cent. of copper, and 0·6 per cent. of antimony. It is of a red-brown color, blown up like foam, and difficult to melt. The copper from the crucible assay of this slag contained neither nickel nor iron. The slag is added to the melting of the residues from the amalgamation. The residue of 150 tons of crude speiss and 200 tons of refining slag has to be worked up by itself yearly, and this forms the most difficult part of the melting operations.

Working up of the Speiss.—Amalgamation.—The speiss is powdered, and a charge of 700 to 900 lbs. is placed into a roasting furnace. Commencing with a slow fire on the grate, this is removed entirely as soon as the speiss begins to glow, and the roasting is performed at the lowest possible temperature. The charge is then taken out, the furnace cooled down, no fire at all given to the grate, and a new charge put in. This in a short time begins to glow, and has to be constantly stirred and turned, and every attention paid that the furnace does not get too hot. In this manner the roasting is conducted for months, without fire on the grate, because there is so much heat remaining in the walls of the furnace, that each new charge begins to glow by itself. The furnace is recharged every 8 hours. The speiss powder, after cooling, is sifted, the lumps are ground, both powders mixed, and turned over to a second roasting. 600 lbs. of this powder roasted without fire are mixed with 100 lbs. of crude speiss, put into the upper furnace, and remain there, being constantly stirred and turned for 5 hours. The crude speiss is added for the purpose of easier setting the mass on fire in the upper furnace. In the fifth hour there are added in the upper furnace, to this charge of 700 lbs., 100 lbs. of crude limestone. After the fifth hour it is lowered down to the lower hearth, where it is mixed with 3 to 4 shovelsful of charcoal dust,—

This is done three times from the fifth to the seventh hour. Now the grate is fired; and in the ninth hour the mass must be bright red-hot; therefore a pretty good fire is kept up, which is extinguished again at the end of the tenth hour; so that can be reckoned in the upper and lower furnace together as follows:

Incension, no fire on the grate	1 hour.
Calcining, (schwefeln,) no fire	7 hours.
Roasting, good fire, bright red heat	1½ hour.
Cooling, no fire	½ hour.

The firing is done by chips and pine branches. It is necessary that during the whole process of roasting the charge be constantly stirred and turned; therefore the upper and lower furnace are furnished each with two workmen, who alternately do the work from hour to hour.

The powder comes from the furnace in a sheet iron wagon, in which it is transported to a corner of the roasting house, where it cools off entirely. 700 lbs. of it are mixed with 49 lbs., or 7 per cent., of salt and 6 lbs. of crude limestone, and then it is given to the lower hearth of a furnace, where it is roasted for 4 hours at dark red heat, which is somewhat increased during the last hour. Chloride of silver is here formed without sulphuric salts being present, which emanate sulphuric acid, and thereby decompose chloride of silver. Then the amalgamation is done quite in the same manner as the amalgamation of the black copper.

On Magnetical Errors, Compensations, and Corrections, with special reference to iron ships and their compasses. By Professor AIRY.

From the London Athenæum, April, 1865.

(Concluded from page 109.)

V. *Magnetism of Ships, especially of Iron Ships, and Correction of Magnetic Disturbing Forces on the Ship's Compass.*—54. Notes on the principal steps made in the investigation of these subjects, by Flinders, Christie, Barlow, Sabine, (for wood-built ships containing some iron;) by the Astronomer Royal's experiments on the *Rainbow* and *Ironsides;* by Scoresby, Liverpool Committee, Towson, Rundell, Evans, (experiments and approximate theory for iron-built ships;) by A. Smith, (inferences from Poisson's general theory, change in the form of the numbers exhibited, and theory of the parallel needle compass.) Speci treatises, "Admiralty Manual," edited by Captain Evans and Archibald Smith, Esq.; "Practical Information," by John Thomas Towson, Esq., published by the Board of Trade. The latter is strongly recommended to nautical men.

55. For theoretical purposes, and for steering a ship, (in a very contracted range of latitude,) by a table of errors of compass, it is necessary to measure the disturbance of the compass in numerous positions of the ship. For the practical purpose of correcting the compass, it is only necessary to place the ship in a limited number of positions; eight (at the utmost) at first, and two in subsequent alterations.

56. Methods of measuring the disturbance of the compass: By observation, with azimuth sights, (at great height above the compass, if necessary,) of a very distant mark, whose true bearing by compass is known. By similar observation of a celestial body, whose astronomical azimuth can be computed and can be converted into magnetic azimuth. (For this purpose a knowledge of the local variation is necessary; it can be taken from Captain Evans' very valuable chart. By reciprocal observations of azimuths with an azimuth compass on shore in a position free from disturbance, (a method practised by the Astronomer Royal for the *Ironsides*, and frequently used since that time.) In circumstances where none of these methods can be used, by observation of a moderately near mark, accompanied with observations which define the position of the compass, and by repeating the observations nearly in the same places upon a wooden raft (as practised by the Astronomer Royal for the *Rainbow*). The selection or invention of the method to be used must be left to the judgment of the operator under the actual circumstances.

57. Methods of conveniently recording the disturbances: By table of errors. By Napier's diagram, with equatorial triangles. By concentric circles.

58. Investigation of the deviations in the *Rainbow*, in which the existing theory was first established. General obscurity on the subject. Deviations of the steering compass amounting to 50° marked end drawn to the east, and 50° marked end drawn to the west, according to the position of the ship's head. The first light thrown upon it was derived from observations of the vibration of a magnet freely suspended in the place of the compass, the observations being made with the ship's head N. E. S. W. The vibrations of the same needle were observed on shore. By comparison of these, the proportion of the acting magnetic force on the ship's compass in those different positions of the ship to the earth's undisturbed magnetic force was found. (The acting force with the ship's head nearly south was ten times as great as with her head in the opposite position.) Thus it was found that, representing the earth's force by 100 towards the north, the ship's polar force was represented by 80 towards the stern, and 17 towards the port side, or by 82 in a direction 12° from the stern. (This is the largest that has yet been observed.) By a graphical construction with these elements, based on the parallelogram of forces, it was found that the observed disturbances were accurately represented, with the exception of a small quadrantal quantity, such as would be produced by the iron of the ship nearly towards the head, or towards the stern, (Article 30.) A magnet of proper intensity was prepared and placed in the proper position to correct the ship's solar force, and a scroll of iron was placed on one side (Article 46) to correct the quadrantal deviation, and the compass was then sensibly perfect.

59. Treatment of the deviations in the *Ironsides*. In this operation was invented the method of using two magnets instead of a single one; a most important step, because it gave the means of effecting the correction without calculation. The ship's head was placed magnetic

north or south, by the aid of a shore compass viewing her masts, and a magnet was placed on the ship's deck in an athwart position, ahead or astern of the compass, and was slid nearer or further till it caused the compass to point correctly. Then the ship's head was placed magnetic east or west, and a magnet was placed in a fore and aft position on the deck on one side of the compass, and was slid nearer or further till it caused the compass to point correctly. The first magnet does not disturb the compass in the ship's second position, and the second magnet does not disturb the compass in the ship's first position. Thus the compass was made correct in the four cardinal positions of the ship. Then the ship was placed in an intermediate position, her head 45° east of north, or west of north, and a mass of iron was placed on one side of the compass to correct quadrantal deviation. Then the compass was sensibly perfect. This is the process which is still universally employed. The object in placing the magnets either below the compass or broadside-on is to avoid introducing a vertical force, which is produced with a magnet end-on, (Article 22.)

60. Exhibition of the process of correction in a model.

61. Description of the different substances which have been adopted for correction of the quadrantal deviation; scroll of iron plate, small box filled with fine iron chain, masses of cast iron, &c.

62. Continuation of history. After a time it was found that the polar magnetism of a ship, which was supposed to be permanent, was not really permanent, and the term "subpermanent" was introduced; in particular, reasons appeared for supposing that the polar magnetism changed rapidly in the course of a ship's first voyages. The Liverpool Committee was appointed to inquire into the whole subject; their three reports are probably the most valuable documents that we possess referring to these questions. The inquiries were conducted principally by Mr. Towson and Mr. Rundell. Among their most important conclusions were these: That the direction of a ship's polar magnetism, as affecting her compass, might always be inferred from the position in which she was built; that, therefore, it was to be concluded that her magnetism was induced by subpermanent magnetism (Articles 37, 38, 39) produced by the hammer blows in uniting the plates when building; that much of this was soon lost, when the ship was afloat, but that a part remained, with little alteration, for many years. The Astronomer Royal discussed the records of several ships of the Royal Navy, and also those of the Royal Charter, and showed that after the first voyages the change of polar magnetism was small, and generally in the nature of diminution. (Dr. Scoresby's special observations on the Royal Charter had no important relation to the ship's compass.)

63. Very important observations on this matter were made by Captain Evans and Mr. Rundell on the *Great Eastern*, which they followed through several stages after its launching. The transversal polar magnetism diminished very greatly.

64. Among the points elicited by the inquiries of the Liverpool Committee was this, that in many, but not in all, of the merchantships which they examined, the correction of the compass effected in Eng-

land failed so much in southern latitudes as to lead to the impression that the ship's polar magnetism had changed considerably. As far as had been observed, there was no similar change in ships of the Royal Navy. Remarking that in merchant ships the compass is nearer to the stern than in ships of the Royal Navy, Mr. Rundell was led to a practical conclusion which ought, in all cases, to receive attention. The history of an earlier discovery is first to be mentioned.

65. Captain Flinders, who made a voyage of discovery in a wood-built ship in the first years of this century, remarked with great accuracy the errors of his compass. with the ship's head in different directions, and with the ship on different sides of the magnetic equator, and with singular sagacity referred their cause to the induced magnetism in the vertical iron stanchions, (Article 27,) which were principally ahead of the compass. He suggested that they might be corrected by placing a vertical iron bar astern of the compass. General Sabine, in discussing later voyages, remarked that the change due to position on the globe did not *immediately* follow the change of ship's position; which showed that the magnetism of the stanchions, &c., partook in some measure of the nature of subpermanent magnetism, (Article 37.) These remarks nearly exhaust the subject of disturbances in wood-built ships.

66. Mr. Rundell, apparently without any knowledge of Captain Flinder's proposal, remarked that the compass of merchant ships is not far in advance of the great vertical iron bar of the stern-post, accompanied in screw steamers by another bar of the rudder-post, and that a magnet which corrected the influence of these bars in north latitudes would increase it in south latitudes, but that a correction valid in all latitudes might be made by fixing a vertical iron bar ahead of the compass. This has been done in several instances, apparently with uniform success. The amount of correction to be produced ought probably to be such as will leave the fore and aft magnetism at that place nearly similar to that on other parts of the ship.

67. The disturbance of the compass is undoubtedly simpler when a ship has been built with her keel in the magnetic meridian, but there does not appear to be any strong reason for deciding between the positions of head north and head south.

68. After every care has been taken, the ship's subpermanent magnetism will change, (usually diminishing slowly,) and arrangements ought to be made for meeting this change. Nothing appears preferable to Gray's adjustable binnacle.

69. For the application of this, it is necessary to be able to place the ship's head once north, (or south,) and once east, (or west,) using for this purpose either a land mark or a celestial body. The dumb card is the most convenient instrument for placing the ship's head in the proper position.

70. Adverting now to the quadrantal deviation. In merchant ships the quadrantal deviation is usually 3° or 4°, or perhaps in a few cases 6°, and in nearly every case it is of that kind which would be produced by a mass of iron exactly ahead or exactly astern of the com-

pass, (Article 30,) and this may be corrected by a mass of iron placed exactly on one side, or by masses placed exactly on both sides, (Article 46,) and an error of 6° is not too great, especially when the four-needle card is used, to prevent this from being done conveniently.

71. But in the armed ships lately built for the Royal Navy with iron decks and iron in every part, the quadrantal deviation amounts to 14°, and it is difficult to correct this by a mass of iron.

72. Perhaps it might be corrected by another compass, (Article 47,) but the same correction would not be valid in different latitudes. (Article 50.)

73. The Astronomer Royal prefers a modified card. (Article 53.)

74. It has lately been discovered by Captain Evans, that in the wood-built ships covered with the thickest armor plates, the quadrantal deviation is small, not exceeding 3° or 4°. This is analogous to what is described in Article 29. It appears to show that the riveting of the plates of an iron-built ship produces what may be called "magnetic contact," but that the juxtaposition of large masses of iron does not produce magnetic contact. In the latter case, the simple theory of the Astronomer Royal, (*Phil. Trans.*, 1839,) appears preferable to the general theory of Poisson. The form of their results is the same, but the co-efficients are different.

75. In the turret ships lately built it has been necessary to place the compasses out of the central line of the ship's deck. That eccentric position modifies the law of quadrantal deviation in this way, that the quadrantal deviation is represented by the effect of a mass of iron not exactly ahead or exactly astern of the compass, but in a direction somewhere intermediate between the fore and aft direction and the transversal direction. The difference which this would make in the correction would be the following: After having adjusted the transversal magnet to make the correction complete with the ship's head north, the correction would be found incomplete with head south; and the adjustment must be altered till the error is divided between the two positions. In like manner with head east and head west. By remarking the magnitudes of the residual errors in different positions, the operator will determine with considerable accuracy the direction of the ship's head when the error is 0; and the mass of iron must be either towards north or south, or towards east or west, with the ship's head in that direction. That choice of positions being determined for the mass, the ship must be turned 45° from the same direction, and the mass is to be adjusted to make the compass correct. A modified card might be adapted to the compass, but it would require a special commencement of readings.

76. The order of operations ought in all cases to be this: (1.) For a compass near the stern, Rundell's vertical bar ought to be fixed. (2.) The two magnets, or systems of magnets, for effecting the correction with the ship's head N.E.S.W. ought to be applied. (3.) The masses of iron for correcting the quadrantal deviation ought to be applied, or the modified card ought to be mounted. These will never require alteration, whatever alteration be made in the magnets. (4.) The ship

should, if possible, be sent on a short voyage, or should be exposed to agitation by the sea, and to tremor by her machinery, in different positions of her head, for several days. (5.) The positions of the magnets ought to be readjusted. It will probably be sufficient to place the ship once with her head north, (or south,) and once with her head east, (or west.)

77. *It is of very great importance that the ship should not be hurried out immediately for a long voyage, but that she should be exposed to agitation and tremors, with her head in different directions, several days at least, and that her magnets should be readjusted before sailing on a long voyage.*

78. On the voyage, the captain should be prepared to readjust the magnets, as is described in Articles 69 and 59, (omitting all that relates to correction of quadrantal deviation, which will never alter.)

79. Some of the methods described in the Admiralty *Manual* relate to the determinations in different localities, and at different times, of the principal elements of magnetic disturbance, as the error of the lubber-line, the subpermanent or other polar forces towards the ship's head and the ship's side, the apparent direction and measure of action of the masses which act by induction, (Article 30,) and the loss of directive power, (Article 35.) In instance of the importance of these determinations it may be pointed out that in iron ships of the Royal Navy the loss of directive power is from one-eighth to one-sixth of the whole. These methods are of the highest value for the philosophical investigations connected with compass disturbance, and are strongly recommended to the advanced mathematician; but they are not likely to be useful in the merchant service.

80. Others of the methods in the *Manual* relate to the possibility of converting a table of errors determined for one locality into a table of errors applicable to another locality. It does not appear probable that such a process can ever be used in the merchant service.

81. On the general question of "correction or non-correction" of the compass, the arguments appear to stand as follows: (It is to be remarked that, if the ship's subpermanent magnetism undergoes a change, it affects both systems with equal injury, and, therefore, that occurrence is omitted in the comparison.)

Non-corrected Compass. *(Using a Table of Errors.)*	Corrected Compass. *(The Binnacle being adjustable.)*
The directive power on the compass is extremely different on different courses.	The directive power on the compass being sensibly constant.
The principal part of the tabulated errors arises from subpermanent magnetism, whose effects in producing deviation vary greatly indifferent parts of the earth, (Article 20.)	The magnets which perfectly correct the subpermanent magnetism in one place will also perfectly correct it in another place.
It is, therefore, absolutely necessary from time to time to make a new table of errors by observations in numerous positions (not fewer than eight) of the ship's head.	Only when there is suspicion of change in the ship's magnetism are new observations necessary, and then two are sufficient, (Article 69.)
In difficult navigation, as in the chan-	In any hydrographical difficulty, the

nels of the Thames or the Mersey, especially with frequent tacks, the use of a table of errors would be attended with great danger.

corrected compass is right on all tacks of the ship, and its use is perfectly simple.

82. The Astronomer Royal has no hesitation in giving his own opinion that the compasses used for directing the ship's course ought to be corrected, and that the efforts of scientific men ought to be directed mainly to the rendering this correction rigorously accurate and easy of application. But the captain, who desires to make his voyages really serviceable to magnetic science, must have one compass on board which either is not corrected, or whose correction is never altered, and must frequently observe it, not for the purpose of steering his ship, but for the collection of magnetical facts. This, however, is to be considered as a philosophical experiment, not as an aid to navigation.

83. The disturbances and their corrections, as treated up to this Article, apply to a ship on even beam, or without any heel; and, by using the methods above described, there is no difficulty whatever in making the correction sensibly perfect. The heeling, at present, offers considerable difficulty, not in estimation of its magnitude, or in application of a correction at any one place, but in doing this in a way which will apply at all parts of the earth.

84. The general law of the effect of heeling is this: When a ship's head is east or west, no sensible effect is produced by heeling. When the ship's head is north or south, heeling produces the greatest effect. Usually, but not in all cases, the marked end of the needle is attracted to the windward or raised side of the ship in north latitudes, and the unmarked end in south latitudes. Usually, in iron ships, with ship's head north or south, one degree of heel produces one degree of disturbance of the compass; but in some instances one degree of heel produces two degrees of disturbance of the compass.

84*. The disturbance by heeling appears to arise immediately from these separate causes:

(1.) Part of the action of the subpermanent magnetism is perpendicular to the deck, and this has not been touched by the operations of correction of the forces in the plane of the deck (if the magnets are applied broadside-on). When the ship heels, this untouched magnetism is inclined to the horizon, and produces partly the effect of horizontal magnetism, and thus disturbs the compass. If the blue end of the magnetism perpendicular to ship's deck is uppermost, it will attract the marked or red end of the compass.

(2.) If there are masses of iron fore and aft of the compass, and also masses of iron to starboard and port of the compass, and other masses added for correction of quadrantal deviation, the masses fore and aft will produce no new effect from heeling, but the masses to port and starboard will be raised on the windward side and lowered on the leeward. The red end of the former, which is its lower surface, will be nearest to the needle, and will repel the marked end; and, in like manner, the upper or blue magnetism of the mass on the lee side will attract it.

(3.) A mass near the ship's keel, considered in the the same way, will have an effect opposite to that of (2), but agreeing with that of (1.)

(4.) A transversal deck-beam nearly under the compass will, on being inclined by the heeling, have blue magnetism in its higher end, which will attract the marked end of the compass, agreeing with (1) and (3). It appears that in most instances the aggregate effects of (1), (3), and (4) exceed that of (2).

85. Attempts have been made to separate these various effects by theoretical considerations, but their success appears doubtful.

86. There appears to be no safe way of determining the amount of the effect of heeling, except by making the ship to heel, and observing how much the compass is effected, either by heaving her down (in dock) or by subjecting her to the action of the wind (on a river or sea).

87. In all cases the effect can be corrected by fixing a magnet below the compass in a position perpendicular to the deck. For, when the ship heels, this magnet becomes inclined, and a portion of its magnetism acts horizontally, and can be made (by trial) exactly to neutralize all the other effects.

88. Gray's binnacles are adapted to receive such a magnet, and to give power of adjusting it. It is carefully to be remarked that this magnet must be mounted and adjusted *after* fixing the masses of iron used to correct quadrantal deviation, (Article 61.)

89. Either the magnet may be adjusted in position while the ship is inclined, or the following course may be pursued: By means of a "clinometer," the ship's inclination may be observed while experiments are made on the deviation, and thus a proportion may be obtained between the angle of heel and the angle of deviation. By means of an experimental pendulum, (whose axis passes through the centre of a compass-card,) on which a magnet can slide, the position may be found at which a magnet will produce the same proportion between the angle of heel and the opposite deviation. The distance of this from the centre of the experimental card is the distance at which the same magnet must be fixed below the ship's compass.

90. On a voyage into southern seas, these experiments ought to be repeated.

90*. And, as a general rule, a corrected compass ought to be considered available in the same manner as a chronometer for longitude. Very great reliance may be placed on it for even very long distances, but it ought to be checked at every possible opportunity.

91. For experiments on iron ships, the following apparatus (among others) may be found desirable: Two or more azimuth compasses, (prismatic compasses also are sometimes convenient.) A dumb card. A vibrating needle for horizontal intensity, either suspended by a silk fibre, or in the form used by Captain Evans. A deflexion needle for horizontal intensity, in Mr. Towson's form. A vibrating needle for vertical force, in Captain Evans' form. A dip needle, balanced to a definite angle, for vertical force, in Mr. Towson's form. An ordinary dipping needle. A clinometer, or pendulum, with graduated arc. A pendulum adapted to carry a magnet. Magnets. Iron for induction experiments. Magnetic anvil.

On National Standards for Gas Measurement and Gas-meters.

By GEORGE GLOVER, Esq.

From the London Journal of the Society of Arts, No. 424.

(Continued from page 123.)

The national standard gas-holders were made at the works of Messrs. Bryan Donkin & Co., whose well-known accuracy in workmanship, and perfect machinery for drawing truly cylindrical tubes of large size, recommended them for such an undertaking. They were constructed under my direction and constant superintendence. In constructing the instruments, the various properties of gas I have just named had to be taken into account, and the following conditions were laid down as essential:

1. That they should be composed of a non-corrodible metal, capable of resisting the chemical action of the constituents of coal-gas and water.

2. That the surface of the bell should readily part with water.

3. That the bell, or measuring part of the instrument, should be a truly cylindrical vessel, and sufficiently rigid to resist change of form from the application of any ordinary forces.

4. That it should have a correct scale engraved upon it to indicate its capacity in cubic feet, and the subdivisions of the feet into minute fractional parts.

5. That it should be correctly balanced, and that a part of the counterpoise, suspended by a cord passing over a spiral, should preserve its equipoise at various depths of its immersion in the water in the cistern.

6. That the sides of the bell should be maintained vertical in its ascent and descent.

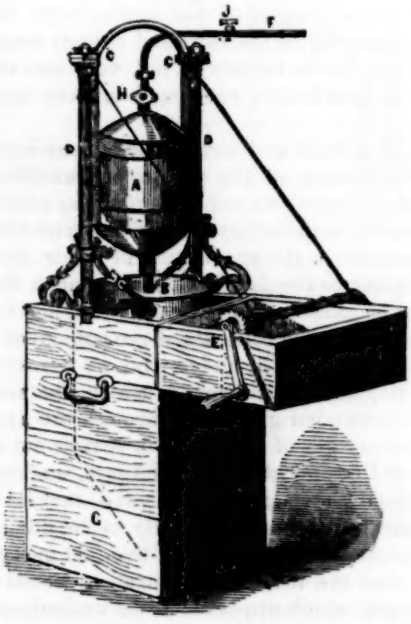
7. That the taps should be lined with the anti-corrosive alloy, and the density of their rubbing surfaces be so varied as to reduce their friction to a minimum, and secure their durability and soundness.

8. That the different parts of the instrument should be so perfectly adapted to each other, that, when put together as a whole, it should work easily, steadily, and correctly.

The standards having been constructed, the next point of difficulty was the application of the cubic foot bottle in graduating them. Their graduation involved nice scientific considerations, and a series of experiments requiring much delicacy and care. I may here state, that in the graduation and experimental adjustment of the standard gas-holders, I received most valuable assistance from Mr. William Græme Tompkins, C.E., who was afterwards employed at the Exchequer in the application of the standards in the verification of the gas-holders for testing meters furnished to the local authorities, and in this his engineering knowledge and experience in the manufacture and use of instruments of precision was of great service. Though the cubic foot bottle already described was accurately adjusted for containing the "legal standard and unit of measure," there was no method known by which it could be used in measuring gas, or in the graduation of

holders. An instrument called a "transferrer" was resorted to. It consisted of "an upper chamber, containing exactly the volume of one cubic foot, and adapted, with proper arrangement of cocks and pipes, by repeated discharges of the water filling the upper chamber into the lower chamber, to discharge in succession any number of volumes of air, each of one cubic foot, into any vessel properly prepared for their reception." This instrument was resorted to without any satisfactory result. It was open to serious objections. The filling of the bottle produced agitation of the water, displacing air from the water, and entangling variable quantities of it in minute bubbles, many of which adhered to the inner surface of the bottle. Every means which suggested itself was tried to make it available, but these giving no satisfactory result, it was laid aside. Analogous methods were tried of

Fig. 2.



GEO. GLOVER'S DIRECT TRANSFERRER.

Scale $\frac{4}{10}$ inch = 1 foot.

A. Inverted cubic foot bottle.
B. Cistern to be raised.
C C. Small pulleys for rope-connecting windlass with cistern.
D D. Pillars to support cubic foot bottle, and to which the pulleys are fixed.
E. Windlass with ratch for raising the tank or cistern.
F. The exit pipe from bottle.
G. The box in which the whole instrument is enclosed.
H. Window covering the aperture made by the withdrawal of the plug of the tap of the bottle.
I. Tap betwixt bottle and holder.

transferring the exact cubic foot of air to the gas-holder, but with hardly more success. A closer approximation in some instances was obtained, but the uniformity was not such as to justify their adoption in the division of the scale. At last it occurred to me that, instead of using the bottle indirectly, it might be used directly, the second vessel being dispensed with. The diagram, Fig. 2, will explain the process.

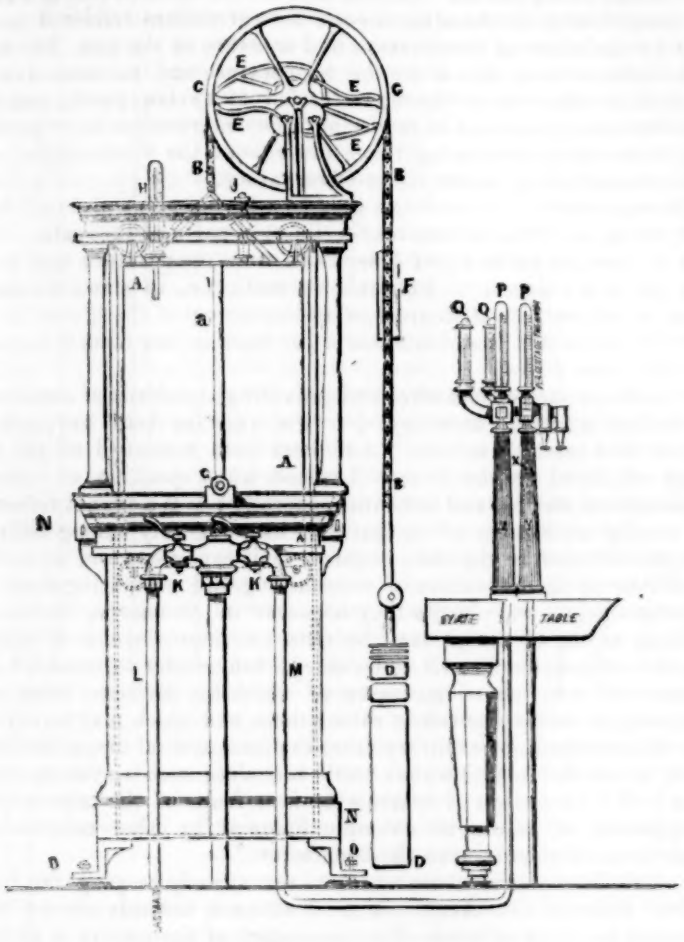
1. The bottle was inverted.
2. The plug was drawn out.
3. The openings caused by the withdrawal of the plug were closed with glass.
4. A piece of leaden tube was soldered to the end of the tap.
5. This tube was connected with the gas-holder to be tested.
6. A cistern containing distilled water was placed below the bottle thus secured in a fixed vertical position.
7. The cistern was raised steadily, without the water being agitated, through the entire length of the bottle, until the water reached the point where the plug of the tap, had it been retained, would have stopped it, and the entire volume of air, viz: one cubic foot, defined by the contents of this bottle, was found to have been transferred to the gas-holder.

By this method, simple and direct, the various errors occasioned by the complicated character of the "indirect transferrer" are at once avoided. Tested by numerous experiments, the results of this method have been invariably satisfactory, and it has removed a difficulty long felt by meter makers in the graduation of their holders for testing meters. In his letter to the Lords Commissioners, from which I have already quoted, the Astronomer Royal, referring to it, says: "The volume of air defined by the contents of the cubic foot bottle was forced into the gas-measurer, Fig. 3, under trial by a process invented and introduced by Mr. George Glover, in which the nearly undisturbed surface of water is carried gradually through the entire length of the bottle without risk either of absorbing or giving out air. For the one-foot gas measurer this operation, in strictness, was required only once, (but, as a cautionary step, it was repeated several times.) For the ten-feet gas measurer it was necessarily to be done ten times. The result of the examination was that the five-feet measurer exhibited no trace of error; that the ten-feet measurer appeared to show an error of about $\frac{1}{3000}$ part, which appeared to be undoubtedly due to a little change of temperature; and that the one-foot measurer, which is extremely sensitive to such changes, apparently exhibited errors, sometimes $+\frac{1}{5000}$, sometimes $-\frac{1}{5000}$. Regarding these indications as merely illusory, I do not doubt that the gas measurers are as accurate as it is possible for human skill to make them, and I therefore report them as being, to all intents and purposes, perfect."

The experience of five years, I am happy to say, has only confirmed this testimony.

In verifying holders, and in testing meters, thermometers of a peculiar construction, Fig. 4, are used with elongated bulbs, by which sufficient delicacy of indication is insured, whether of the testing room,

Fig. 3.



A A. Inverted cylindrical vessel, commonly called the bell.
a. The scale engraved on the bell.
B B. Chain or band by which the bell is hung.
C C. Wheel or pulley over which the chain or band works.
D D. Counterbalance weight for the bell; upper parts movable, so as to give the two pressures required by Clause 13 of the Act.
E E. The cycloids or spirals fixed on the pulley-shaft, and balancing each other.
F. A counterbalance weight attached to the extremity of one of the cycloids to maintain the true balance of the bell at varying depths of the water.
G. Microscope for reading the scale.
H. Thermometer on the bell.
J. Pressure-gauge on the bell.
K K. Taps.
L. Inlet pipe.
M. Outlet pipe.
N N. Cistern or tank.
O O. Adjusting screws for leveling cistern.
P P. Thermometers on testing-table.
Q Q. Pressure-gauges on table.
Y. Exit column from secondary.
Z. Exit column from standard.

the standard bell, the outlet of the standard bell, or the outlet of the instrument being tested. On one side of the thermometer is a scale for temperature, on the other a scale for corrections rendered necessary by variations of temperature and moisture in the gas. The scale is calculated from the tables for temperature and moisture kept at Greenwich Observatory during a period of twelve years, and Mr. Glaisher kindly assisted in rendering these instruments more perfect, and in carefully comparing them, throughout the whole scales, with the standard thermometer at the Observatory.

Thermometers in general use vary to a large extent, not only from each other, but from themselves, in different parts of the scale. Gas, as you know, expands about $\frac{1}{4}$ per cent. from temperature and moisture for every degree of Fahrenheit's scale, *i.e.*, in round numbers, about 5 per cent. for 20 degrees. Gas coming out of the ground at the temperature of 40° would increase 5 per cent. in this room if the temperature were 60°.

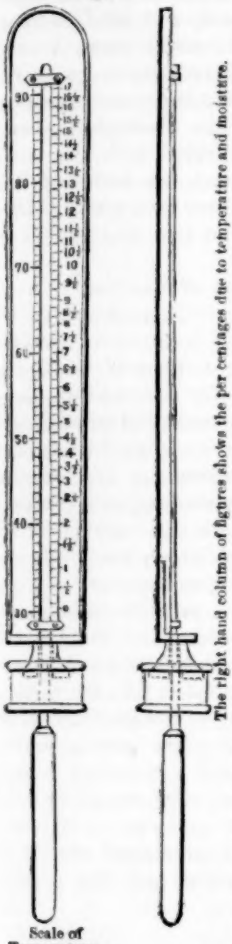
In fixing a unit of measure, and providing standards of measure of the highest attainable accuracy, the "Sales of Gas Act" has rendered a great and valuable service. And here I am reminded of the language employed by the famous Laplace, when speaking of national standards for weights and measures generally: "We cannot reflect on the prodigious number of measures in use, not only among different nations, but even in the same country, their capricious and inconvenient divisions, the difficulties of determining and comparing them, the embarrassments and frauds they occasion in commerce, without regarding, as one of the greatest benefits, the improvements of science and the ordinances of civil government can render to mankind, the adoption of a system of measures, of which the divisions being uniform, may be easily derived in calculations, and which may be derived in a manner the least arbitrary from the fundamental magnitude indicated by itself. A nation that would introduce such a system, would unite to the advantage of reaping the first fruits of the improvement the pleasure of seeing its example followed by other countries, of which it would thus become the benefactor."

And so, in the present instance, we are already reaping the fruits of the "Sales of Gas Act." A great advance towards correct measurement has been effected. The inaccuracy of the meters in general use hitherto has been fully established. The companies and the community can now be protected. So far the legislature has done its duty. Lord Redesdale's Act carried legislation as far as the present state of our information justified, and it avoided the grave error of going beyond it. The prudent and wise course for government to pursue is clear. It is at once its duty and its interest to protect, encourage, and give every facility to a manufacture now so intimately connected as gas is with the public welfare.

And here, I may remark, in passing, that the clamor now being raised against gas manufactories being conducted in the heart of our

cities and towns is unreasonable. It has gained strength from the recent explosion of a gas-holder not far off, a circumstance which has excited needless apprehensions. No occurrence could be more exceptional. I believe it is without precedent, and it arose from a circumstance which might easily have been prevented. When, in 1854–55, I had the honor to be instructed by Sir Benjamin Hall (now Lord Llanover) to examine and report on the gas-works of the metropolis, for his guidance, with reference to the "Nuisances Removal Act," I reported that gas-works could be conducted in populous neighborhoods without being a nuisance or injuring the public health. Legally to constitute a nuisance three things must be established: A noxious element in sufficient quantity; that element in sufficient intensity and in continuous action; and gas-works were not declared such a nuisance. To science, in fact, and not to legislation, must the public look for the removal or mitigation of any evil or danger which they may occasion.

Fig. 4.



But to return. The government having done its duty, it should be the endeavor, as it is the interest, of meter manufacturers to produce meters such as will satisfy the just demands of the public. The work of reform in the measurement of gas which emanated from the legislature must be carried on systematically and earnestly throughout the community. Neither party interests nor party prejudices can be permitted to obstruct the public weal. Old monopolies here, as in other kinds of manufacture, injurious in the first instance to the public, and eventually to the monopolists themselves, must be considered among things that were, and the principle of free and unrestricted competition—"a fair field and no favor,"—as the only principle which can secure the benefits the "Sales of Gas Act" was meant to yield. Mere slop work, the bane of every other kind of manufacture, must be done away with in this. Slovenly workmanship, bad materials, "rough and ready," "finger and thumb" adjustment, whether of the wet or the dry meter, must give place to careful execution, suitable materials, and correct mechanical adaptations.

In respect to the wet meter the following points may be considered as clearly established: That, with the introduction of water, the proverbial instability of water is introduced; that the level of the water is disturbed by the pressure of the gas constanly varying; that the

use of the wet meter exposes the companies to severe loss, and those who use them to annoyances and dangers from which dry meters are comparatively exempted; that corrosion from the action of the constituents of coal-gas and water is actively at work, and fatal to their durability. Of late it has become customary to make cases of cast iron, to conceal the corrosion, without reference to what is going on internally, and, by repeated coatings of green paint, to convey the idea of soundness, an idea which is simply delusive. Mr. Hawksley, whose knowledge and experience on every subject connected with gas entitles his testimony to much weight, stated before a committee of the House of Lords that, in 1864, in the Nottingham gas-works, 330,000,000 of cubic feet of gas had been made, and that 50,000,000 of cubic feet of that quantity had not been paid for.

No doubt he attributed a considerable portion of this loss to over consumption in the street-lamps, and to leakage. The public will be astonished when told that, even at present, most companies acknowledge that, of the whole gas manufactured by them, from 15 to 20 per cent. is lost or unpaid for, a loss which is usually ascribed to leakage. Most gas companies, as a rule, have no correct method of ascertaining the exact amount of loss; but, whenever the question is carefully gone into, and accurate methods of measurement applied, the loss out of profits is found to be from 20 to 25 per cent., and, in some instances, even more. About 15 per cent. of this loss may fairly be put down to defective meters. The tenacity with which many companies have clung to the wet meter, and their efforts to maintain it, have been in no small measure owing to the want of a suitable substitute, and the failures which, with one exception, have marked the history of the dry meter manufacture. These failures may be traced to one or other of the following sources: The inadequate scientific knowledge of the manufacturers themselves; the complexity of the conditions the manufacture involves; the error of adopting angular movements in the measuring chambers instead of direct action; the use of rotary valves; the difficulty of arriving at the combination of metals in such definite ratios as to constitute a true alloy, the uniform density and structure of which shall be such that, when manufactured into a D slide valve, the rubbing surfaces shall wear equally, and the perfect soundness of the valve shall be maintained.

(To be continued.)

Recent Researches on Metals and Alloys. By Dr. F. Crace Calvert, F.R.S., F.C.S.

(A Lecture delivered May 16, 1865.)

From the London Journal of the Society of Arts, No. 677.

The importance of the subject which I intend to bring before you this evening is so extensive, that it ought to be the subject of a series of lectures instead of attempting to condense it into one, and therefore I shall only give a *resumé* of some of the discoveries which have been made during the last two years.

You are probably all aware that England occupies the first position among nations as a source of mineral wealth, and to enable you to appreciate the truth of this assertion, allow me to cite a few figures published by Mr. Robert Hunt, F.R.S., the keeper of mining records at the Royal School of Mines. In 1863 the value of minerals produced was £29,151,976, from which metal of the value of £36,364,327 was extracted. There were produced—

Tin ore	15,170 tons.
Copper ore	212,947 "
Lead ore	91,283 "
Silver ore	88 "
Zinc ore	12,941 "
Iron ore	3,500,000 "

Further, it is interesting to compare the results given by Mr. Hunt, in 1858, with the above, for we find that the mineral wealth of England has nearly doubled in five years; for in 1858 the value of the metals produced amounted only to £18,105,708. I must not omit to state that, during the last few years, England has also taken the lead in the manufacture of aluminium (Jno. Bell & Co., manufacturers, Newcastle) and magnesium, by Messrs. Mellon & Co., Salford, who have adopted the method proposed by Mr. Sonstadt. As to the four new metals which have been of late discovered, viz: cœsium, rubidium, thallium, and indium, they are as yet but scientific curiosities, but as their discovery is due to spectrum analysis, I shall refer to them more especially when treating of the method by means of which the discovery of these metals has been made, an illustration of which I shall be able to give, through the kindness of Mr. Ladd, who will show you the various spectra on the screen at the conclusion of the lecture.

Since I had the pleasure of drawing your attention last year to the then novel application of magnesium to the art of photography, owing to the intense light which that metal produces, (for it has been calculated to be equal to $\frac{1}{525}$ part of that solar light, and has been seen at a distance of 28 miles at sea, and also to its intense actinic power,) Mr. Bultinck has proposed the substitution of this metal for zinc in galvanic batteries, and states that he believes the substitution would prove a very advantageous one to electricians. The employment of this metal will be greatly facilitated by the large works which have been erected for its manufacture at Boston, in America.

Although Mr. Faraday observed many years ago that light was transmitted through thin leaves or sheets of the following metals: platinum, palladium, rhodium, gold, silver, copper, tin, lead, iron, and aluminium, still we were not prepared for the interesting results that Mr. Quincke has obtained and published in the *Philosophical Magazine* for March, 1864. That gentleman endeavored to determine directly the velocity with which light travels through metals, and he found, strange to say, that it travels faster through gold and silver than through a vacuum. Further, he adds that he was unable to detect any difference in the components of the light which had previously passed through transparent substances, such as plates of glass. The

comparative rapidity of light in passing through metals and a vacuum appears to me to be in favor of the new theory of light, which I took the liberty of expounding to you in my first lecture. Although we could conceive the passage of light through a thin film of metal, still chemists were astonished when Mr. Henry St. Claire Deville, whose name I have had the pleasure of often citing in these lectures, published, conjointly with Mr. Troost, some interesting papers on the porosity of substances under the influence of high temperatures. His experiments enabled him to show that even platinum and wrought iron tubes, the latter one-eighth of an inch thick, are, when carried to a high temperature, permeable to gases. The importance of these results cannot be overrated by chemists, when the permeability of platinum is considered, as that metal has been employed by them under the conviction that its high density and mode of manufacture destroyed all porosity. As to iron, the knowledge of that fact is most important, especially in the manufacture of coal-gas, where iron retorts are used for distilling the coal. So complete is the permeability of iron at a high temperature, that an iron tube, which had been filled with hydrogen gas before the experiment, was found to contain only a trace of it at the end of a few hours.

Considering the short space of time which I have at my command, I can only state that you will find in the Royal Society's Transactions (vol. 152, part 1, page 1) a most elaborate paper on "The Influence of Temperature on the Electrical Conducting Power of Metals," and also (vol. 150, part 1, page 85) one on the "Conductibility of Copper." These researches of Dr. Mathiessen deserve the close attention of all electric telegraph engineers.

The study of metals must convince every student that, although science has progressed in a marked manner during the last fifty years, still that there is a great deal more to do than has been done. Although we have known copper, zinc, lead, tin, and iron for many centuries, still hardly a month passes without new properties of these metals being discovered, or facts connected with the improvement of their manufacture, or the removal of the impurities they contain. I therefore deem it my duty to advert to a few papers that have been published recently respecting certain impurities which particular metals contain, which impurities, in some instances, enhance the value of the metal, and in others lower their commercial value. No class of substances teaches the young chemist the difficulties and the labors he must be prepared for, if he wishes to be what is technically termed a good operator, and if he pretends to prepare a *pure* substance. I would therefore advise all young men studying chemistry, carefully to read the labors of J. S. Stas on "The Determination of the Equivalents of Chlorine, Sulphur, Nitrogen, Silver, Potassium, Sodium, and Lead," published in the *Moniteur Scientifique* of 1861 and 1864, where they will notice that Stas has spent months of time to obtain a few ounces of *pure* silver, lead, &c.

Copper.—The same may be said of the researches of Mathiessen to obtain pure copper, for his studies above alluded to have enabled

him to state that there is no alloy of copper which conducts electricity better than pure copper, (page 92 of the above memoir,) for he found that the most minute quantities of arsenic, phosphorus, sulphur, selenium, tellurium, and oxygen diminished the conducting power of that metal. Whilst on the impurities of copper, I must not fail to mention some valuable additions which Messrs. Abel and Field have published in the *Journal* of the Chemical Society of London, on the means of determining various impurities which copper contains. Thus they found sometimes traces, and sometimes several per cent., of the following impurities in many samples of commercial copper, silver, arsenic, antimony, bismuth, lead, tin, and iron, (see tables, vol. 14, page 302,) and Mr. Abel, in a paper inserted in the same journal in 1864, proved that copper contained sulphur, as a general constituent, but only in minute quantities; selenium, as an occasional constituent; and that oxygen was always present, and sometimes in considerable proportion. Thus, in dry copper he found the quantity of oxide of copper, not as Messrs. Dick and Percy have stated, from 10·21 to 9·34 per cent., but from 3·77 to 4·56 per cent. Mr. Abel gives the following numbers as representing the average proportion of oxygen obtained with a series of samples, taken in diverse stages in the manufacture of copper:

	Oxygen per cent.
"Dry" copper	0·42
Do., (another specimen)	0·50
"Half-poled" copper	0·20
"Tough-pitch" "	0·03
"Over-poled" "	0·03

Iron.—As far as our present day's knowledge extends, no metal is more influenced than iron, either for good or for bad, by the presence in it of a minute quantity of another element. Thus, a few thousandths of carbon transform it into steel, and a few per cent. of the same element converts it into cast iron; a few thousandths of sulphur, or a few per cent. of silicium, renders iron "red-short," that is to say, brittle at a red heat, whilst the same quantity (thousandths) of phosphorus makes it "cold-short," or brittle at natural temperature. These facts explain why iron smelters and manufacturers do all in their power to use ores as free as possible from these impurities, or apply all their skill to remove them from the ores or metal when present. I am therefore satisfied that all iron smelters will appreciate the value of the following facts, published by M. Caron in the *Comptes Rendus* of the Academy of Science of 1863, on the influence of manganese, when used on the blast furnace to remove silicium from cast iron. The following table shows the relative quantity of manganese and silicium existing in the cast iron thus produced:

	Manganese.	Silicium.
No. 1	7·93	0·05
" 2	6·32	0·08
" 3	4·70	0·30
" 4	3·81	0·55
" 5	2·25	0·76
" 6	3·90	0·50 cold blast.
" 7	2·10	0·75 hot blast.

This table shows that as the quantity of manganese decreases in the pig iron, the quantity of silicium increases; further, that the higher the temperature (all the rest of the operation being conducted in the same manner) the quantity of silicium increases and the manganese decreases.

M. Caron has further made the important remark, that it is the interest of the iron smelter to use as much lime in the blast furnace as practicable, when manganiferous ores are employed; for not only does lime facilitate the introduction of manganese into the iron, but also helps in a marked degree to remove the excess of silicium.

Eight or nine years ago I made the observation that if manganese had not the property of removing phosphorus from iron, it had the one of hiding or of counteracting the bad influence of that element on iron; in fact, I found that cast iron, containing as much as one or two per cent. of phosphorus, would yield good mercantile iron if the pig-iron contained at the same time five or six per cent. of manganese, and I have lately heard that manganiferous ores have been used with great advantage by the Cleveland iron smelters to overcome the "cold shortness" of their cast iron, which is due, as is well known, to the presence of phosphorus compounds in the Cleveland iron ore.

It is highly probable that the advantages which have been derived from the employment of "spiegeleisen" iron, in improving the quality of steel produced by Bessemer's process, is owing, not only to the fact that this peculiar iron contains a large quantity of carbon, which it yields to the molten iron contained in the large crucible used in Bessemer's process, but that the manganese it contains contributes also to hide the influence of the phosphorus, or to overcome the detrimental properties which a trace of phosphorus would impart to the steel produced by this process. I say hide, because the phosphorus is still present, since that substance cannot be removed by the above process from any pig iron in which it may be present.

M. Caron has published in the *Technologiste*, for 1864, a paper, in which he shows that no amount of lime on the blast will remove phosphorus from any ore which may contain it; and that tin-plate manufacturers and others who employ charcoal iron, should pay the greatest attention to the quantity of phosphorus contained in the charcoal they employ for refining ordinary iron. Thus some charcoals are susceptible of yielding as much as 1 per cent. of phosphorus to iron, whilst others only 0·12 per cent., and lastly, some only a trace.

If phosphorus, sulphur, and silicium are injurious to the quality of iron, the metal called tungsten, on the contrary, appears to improve in a marked degree its quality, especially when in the state of steel. This fact has not only been demonstrated beyond all doubt by Mr. Mushet, but also recently by some scientific researches due to M. Caron, who has proved that steel containing tungsten presents greater tenacity, and can be used with great advantage for many purposes; in fact, he thinks that tungsten can be used instead of carbon as a converter of iron into steel. There can be no doubt that the employment of tungsten, in connexion with the hardening of steel, and other

various applications which that metal is susceptible of, will be greatly enhanced if the fact stated in the *Chemical News* of August 25th is brought to bear, viz: that a Swedish chemist has found a simple and practical method of extracting tungsten from its ore so as to reduce its cost of production to a few shillings per pound.

Mr. R. Johnson and myself have published a paper in the Memoirs of the Royal Society, in which we showed that the conductibility of iron was greatly modified by the quantity of carbon it contained, as proved by the following table:

	Found.	Conductibility of silver = 1,000.
Wrought iron	13·92	436
Steel	12·65	397
Cast iron	11·45	359

We also found that the hardening of steel had the greatest influence on its expansibility; for whilst a steel bar, hardened to the maximum, expanded to a degree which may be represented by 84, the same steel, rendered as soft as possible, expanded only 62.

Although the oxidation of iron, or its rapid destruction under the influence of the carbonic acid and the oxygen of the air, is a source of great advantage to those who manufacture this article, still, in many instances, it is a source of annoyance to those who possess articles made of that valuable metal, and in others it is a national loss, as in the rapid decay which our iron ships of war undergo. Allow me, therefore, to say a few words on these points.

It is easy to preserve small articles made of iron from rust, either by plunging them into a weak solution of caustic alkali, (whether the iron is preserved by a peculiar action of the alkali, or because it prevents the action of the carbonic acid of the atmosphere in conjunction with oxygen and moisture, are points to be determined,) or covering them with a varnish made of india rubber, gutta-percha, and a small amount of fatty matter. As to the preservation of ships' bottoms from corrosion, without entering here into the various methods that have been proposed of late to effect this important object, still I deem it my duty to call your attention to one or two methods that have been tried with apparent success. Thus Mr. Leach has applied on the iron surface of ships' bottoms a coating of gutta percha or other cement, and fastening by it sheets of glass of about one-fourth of an inch in thickness. The glass is previously bent to the shape of the ship, and pierced for the reception of the screw or bolts, which are preserved from immediate contact with the metal bolts by coating them with a little of the fastening mixture.

M. Becquerel relates, in the *Comptes Rendus* of the Academy of Sciences, 1864, the results which he obtained by the application of his galvano-electric process on the iron keels of some of the French men-of-war. This process is based on the same principles as those adopted by Sir Humphrey Davy, in 1824, for preventing copper sheathing from being rapidly corroded by sea-water, and which consisted, as you are aware, in attaching at various distances blades of zinc between the

wooden side of the vessel and the copper sheets, or, what effected the same purpose, in using brass nails for fastening the copper to the sides of the vessel.

M. Becquerel employs zinc in connexion with iron, thus establishing a galvanic current which renders the iron, like the copper in Sir. H. Davy's experiment, electro-negative, or possessing the same kind of electricity as oxygen; therefore communicating to it the property of liberating oxygen from any compound, instead of absorbing or fixing it. M. Becquerel has proved that the galvanic action of the zinc on the iron exercises its influence on the whole of the iron surface of the ship, but nevertheless that its influence decreases as the square of the distance, and consequently that its action is only sufficiently powerful to preserve iron from corrosion for a limited distance, and consequently the preserving bands of zinc must be placed at short intervals from each other.

Mr. Johnson and myself published, as I hope you will remember, in the *Journal* of the Society, two or three years since, two papers bearing upon this same subject, the first paper containing facts exactly identical with those published in 1864 by Becquerel: the second showing the advantage that would be derived by ship-builders in using galvanized iron plates, instead of wrought iron ones, for plating our men-of-war, for you are aware that the attack of sea-water on iron plates in contact with oak was very great, being 2·880 as compared with galvanized iron, which was only of 0·095, all the circumstances of action being equal in both cases.

But the most important result that Mr. Johnson and I have arrived at on this point, is the demonstration, in a paper we have published, on "The Action of Sea-water on certain Metals and Alloys," that the action of sea-water on lead is nearly *nil*, as seen by the following table:

Action of Sea-water upon Metals.

1 Metre.	Grammes.
Steel	29·16
Iron	27·37
Copper (best selected)	12·96
Do. (rough cake)	13·85
Zinc	5·66
Galvanized iron (Johnson's process)	1·12
Block tin	1·45
Stream tin	1·45
Lead (virgin)	trace.
Lead (common)	trace.

This metal can, therefore, be used with great advantage to preserve the keels of iron ships from being corroded by the action of sea-water, and that the objection which might be raised as to its softness might be easily overcome by adding to lead a few hundredths of either arsenic or antimony, which would increase its hardness, and thus render it better fitted for the purpose referred to. From experiments that we have made we can further state that, in our opinion, Muntz's metal is a far superior article to copper for sheathing ships. (See *Society of Arts' Journal*, April 21, 1865.)

As a few ladies have done me the honor to attend these lectures, it may be interesting to them to have a simple method of cleaning silver, or silver-plate, without the trouble of employing rouge or other cleaning powder, which, besides rapidly wearing off the metal, takes up much of their servant's time. It consists in plunging for half an hour the silver article into a solution made of 1 gallon of water, 1 lb. hyposulphide of soda, 8 ozs. muriate of ammonia, 4 ozs. liquid ammonia, and 4 ozs. cyanide of potassium; but as the latter substance is poisonous, it can be dispensed with if necessary. The plate being taken out of the solution, is washed and rubbed with a wash leather.

Improvements have also been made of late in coating cheap metals, such as iron and brass, with more valuable ones, so as to enhance the value of the fancy articles made with them. If you remember, I referred to a process devised by Mr. Oudry for coating cast iron with copper or bronze. The method that I wish now to bring before your notice is one devised by Mr. Weil, and is based on the same principle as the one which has been in practice for some time in tinning iron pins, or covering brass with gold, viz: plunging the article to be coated into a boiling alkaline solution of a salt of tin, or a salt of gold, and, in the case of Mr. Weil, into one of copper, which consists of an organic salt of copper, (say the double tartrate of copper and potash,) with an excess of alkali, taking care that the cast or wrought iron to be coated is in contact with a brass wire during the operation.

I shall now take the liberty of dwelling for a short time on various memoirs which have been published in connexion with the physical properties and chemical composition of alloys.

You will find in the "Transactions of the Royal Society," vol. 150, some extensive researches by Dr. Mathiessen on "The Electrical Conducting Power of Alloys;" also in vol. 154, on the influence which heat exercises on that important physical property of alloys. Mr. Johnson and myself have published papers on the density of alloys, as well as on the hardness, expansion, and conductibility of the same. It was admitted, some years ago, that alloys were simply a mechanical mixture of various metals, but the systematic researches which we have published leave no doubt that when certain metals, such as tin and copper, bismuth and lead, zinc and copper, are employed in equivalent quantities, and that the proportion of each metal does not exceed two or three equivalents of one, to one equivalent of the other, that they are susceptible of combining and forming definite compounds. I may state, in corroboration of this statement, that if one equivalent of zinc and one equivalent of copper are melted together, or 49·32 of copper and 50·68 of zinc, and well stirred, and allowed to cool until a crust is formed on the surface, and then a hole be made in the crust, and the fluid portion poured out, well-defined prismatic crystals, sometimes of ¼-inch long, will be found to coat the interior of the solidified mass, whilst if 45 per cent. of copper and 55 per cent. of zinc, that is to say, proportions which are no longer equivalent to each other, then, instead of obtaining a fine golden colored crystalline alloy, a white amorphous mass will be produced; in fact, no brass founder attempts

to use more than 40 per cent. of copper to produce brass, for experience has taught him that if he exceeds that quantity, he obtains such a white metal that it is no more a marketable article. Another example is furnished by certain alloys for bronze. Thus, when two equivalents of tin for one equivalent of copper are employed, the conductibility of this alloy for heat is equal to that of both the metals together entering into its composition, whilst if the conductibility of alloys, composed of three equivalents of copper to one equivalent of tin, or four equivalents of copper to one equivalent of tin, is ascertained, it will be found that their conductibility is quite different and independent of that of the metals entering into their composition; in fact, the conductibility of four equivalents of copper and one equivalent of tin is five times less than the one first cited.

Without occupying your time with further instances, let me call your attention to an important fact that Dr. Mathiessen, Mr. Johnson, and myself have observed, viz: that the addition of a small quantity of a metal, which may be considered as an impurity, completely modifies, in many instances, its properties, and the most important example that I am acquainted with, is the influence which the addition of one or two per cent. of iron exercises on the properties of brass. If a brass be composed of 60 per cent. of copper and 40 per cent. of zinc, it will be susceptible of being drawn or bent when cold, but cannot be forged or worked when heated, whilst if 1·75 or 2·0 per cent. of iron be substituted for the same quantity of zinc, then a most valuable brass is obtained, for not only is this brass capable of being forged at a red heat like iron, but its tenacity is increased in an enormous proportion, for each square inch of surface is able to support a "breaking weight" of from 27 to 28 tons, a tenacity nearly equal to that of iron.

Messrs. Beyer & Peacock of Manchester, who experimented with bolts made of this alloy, in the hope of substituting them for iron ones in the fire-boxes of locomotives, found that these bolts would support a strain equal to those of iron, and that the threads of the screw were not stripped with more facility than those of iron when exposed to the same strain.

There is no doubt that when this alloy becomes more generally known, many valuable applications of it will be made in the arts and manufactures.

Whilst dwelling on valuable brass alloys, let me state that two alloys have lately been introduced which will prove useful to those requiring them, namely, a white alloy, which is chiefly employed for the bearings of the driving wheels of locomotives, owing to its extreme hardness, and which is composed of—

Zinc	77
Tin	17
Copper	6
	100

The other alloy has been lately proposed to calico printers by Mr.

Lenssen as a substitute for the steel blades used by them to remove the excess of color which adheres to the surface of their printing-rollers, and which blades bear the name of "doctors."

Mr. Lenssen's metal is composed of—

Tin	4·93
Zinc	9·78
Copper	85·29
	100·00

This alloy is stated to have all the flexibility, tenacity, and hardness required for the "doctors" used in calico printing; and further, it presents the great advantage of not being acted upon by acid liquors, which action is often a great source of annoyance to calico printers.

I shall conclude this lecture by alluding to the extraordinary modification in the fusibility of metals when several are fused together. Thus, for example, the following well-known alloys, which liquify in boiling water:

	Newton's alloy, fusible at 212°.	D'Arcet's alloy, fusible at 201°.
Bismuth	5	8
Tin	3	3
Lead	2	5

Whilst the fusing point of these metals, when taken separately, is as follows:

Bismuth	513°
Tin	451°
Lead	620°

Therefore the fusing point of each metal is several hundred times higher than when they are mixed in the above proportions.

A still more fusible alloy has lately been brought before the notice of the public by a Mr. Wood, in one of the American journals, in which he states that by melting together

Lead	8 parts.
Bismuth	5 "
Tin	4 "
Cadmium	3 "

An alloy is obtained whose point of fusion is equal to 140 degrees; therefore susceptible of being used with great advantage for dental purposes.

I have now to refer to the four metals which have recently been discovered, viz: cœsium, from *cæsius*, "sky-colored," owing to two blue lines which it produces in the spectrum; rubidium, from *rubidus*, "dark-red," owing to the existence in its spectrum of two red lines of remarkably low refrangibility; thallium, discovered by Mr. William Crookes, and which derives its name from *thallos*, "a budding twig," symbolizing the beautiful green tint of budding vegetation; indium, discovered by Messrs. Reich & Richter of Freiburg; all of which are due to the introduction into science of a mode of investigation known as the "spectrum analysis."

The principle upon which this mode of research is based has been of late so well described and illustrated by Dr. Wm. Allen Miller, in a paper read before the Pharmaceutical Society, (see Society's *Journal*, February, 1862,) and by Professor Roscoe in four lectures at the Royal Institution, London, (see *Chemical News*, vols. 5 and 9,) and which lectures have received such a wide publication that I think it useless here to enter into details, and more especially as Mr. Ladd will illustrate, by means of his powerful electric lamp, the spectra of some of the above metals, as well as those of potassium, strontium, barium, &c.

Locks and Keys.

From the London Journal of the Society of Arts, No. 708.

At a recent meeting of the Institution of Mechanical Engineers, a description of a new construction of lock and key was communicated by Mr. J. B. Fenby, of Birmingham. The writer pointed out that in all previous locks there had been two important defects in principle, which are fatal to their security—the first being that, although access to the works of the lock is greatly impeded by the many ingenious contrivances, they still admit of the works being got at through the key-hole, and thus allow of a series of attempts being made to pick the lock; while the second defect is the possibility afforded for repeating the trial of a false key, and thus perfecting it by successive alterations after trial. In the new lock described in the paper, which is the invention of the writer, the principle is adopted of dividing the key into two parts, the bit or portion by which the levers of the lock are raised being separate from the stem or handle of the key. For unlocking the lock the bit is inserted through a second key-hole into a radial slot contained in a solid rotating cylinder, the cylinder being then turned round by the stem of the key acting in the centre key-hole; the bit while being carried round is also pushed outwards along the radial slot by means of a cam, and is thus made to protrude from the circumference of the cylinder sufficiently to act upon the levers of the lock, and thereby set the bolt at liberty to be withdrawn. The bit is then pushed out of the radial slot, and drops into a receptacle inside the door; and the further revolution of the cylinder withdraws the bolt, and unlocks the door. The consequence of this mode of construction is that, as soon as the bit has been inserted in the lock and the cylinder turned round for unlocking, the radial slot in the cylinder is carried away from the key-hole, which is completely closed by the solid cylinder, whereby all access to the interior of the lock through this opening is effectually prevented, nor can anything be passed into the lock in this way except a detached bit of metal not larger than the bit by which the lock is opened. The centre key-hole, into which the stem of the key is inserted for turning the cylinder is simply a blind socket with parallel sides, and without any communication with the interior of the lock. The only possibility of opening the lock by fraudulent means lies, therefore, in the use of a counterfeit bit intro-

duced into the lock in place of the true bit; but this counterfeit is absolutely lost to the operator and retained inside the safe at the very first trial, so that he is not only limited to a single attempt, but from the attempt itself no clue whatever is obtained as to the nature of the defect in the counterfeit. In consequence of the levers not being accessible for feeling through the key-hole, and, therefore, not requiring to be all shaped to the same average curve at the portion acted upon by the key, each lever can be shaped to its own proper curve, and the play in the action of the levers is thus reduced to a minimum; hence a much slighter amount of error in the counterfeit than is admissible in the case of previous locks will prevent its opening this lock. The importance of these advantages in the principle of the new lock is illustrated by the celebrated bullion robbery of the South-eastern Railway some years ago, which attracted special attention from the remarkable skill with which it was accomplished and the large value of the property stolen; but even in this case success was not attained until as many as seven trials had been made with the same false key, the latter being altered after each trial according to the indications obtained from the trial, until it was at last sufficiently perfected to be capable of opening the lock of the bullion safe. In that instance also the successive trials were made without leaving any indication behind that the lock had been fraudulently attempted, although it was fitted with detector contrivances for this special purpose; but in the present lock the false bit, being retained inside the safe, is found when next the safe is opened, and furnishes proof of the fraudulent attempt having been made, as well as showing how near the counterfeit key has approached to the original. The locks are made with six levers, and the corresponding steps in the bit are cut with the greatest accuracy by a machine specially contrived by the writer for the purpose, with a permutating arrangement, having an extent of permutation admitting to each lock differing from every other lock made. For locking the lock, the stem only of the key is required, as the bolt is shot simply by turning the cylinder; and as the key-hole for the stem is made with a notch cut out on one side only, while the cylinder is not permitted to make a complete revolution, the key-stem cannot be taken out of the lock whilst it remains unlocked. This lock has an important advantage in simplicity as well as solidity of construction, as there are no more than sixteen separate pieces altogether in the complete lock. Moreover, as both key-holes are simply blind holes with parallel sides, having no communication with the interior of the lock, they do not admit of injury to the lock by the explosion of gunpowder. Specimens were exhibited of the new lock, the action of which was shown both with the true key and with counterfeit keys; and it was shown by trial that the counterfeit failed to open the lock, notwithstanding that, by means of the permutating cutting machine, it had made a much nearer approach to a perfect copy than was practicable in the best hand-work from a wax impression. The key-cutting machine for cutting the bits was also exhibited, having been lent for the purpose by Messrs. Whitfield, of Birmingham, the makers of the lock.

Photographing Cannon Balls.

From the London British Journal of Photography, No. 323.

Some few months ago, when on a visit to Woolwich Arsenal, we were shown by Mr. M'Kinlay, Proof Master, some photographs taken of guns while being fired, which not unnaturally excited feelings of surprise. So rapid had been the exposure, and so well had the proper moment for the exposure been seized, that the projectile could be seen protruding from the cannon's mouth while in the act of proceeding on its distant mission. Mr. M'Kinlay kindly afforded us every requisite information relative to his invention for securing such wonderful results; and, from the fact that the comparative efficiency of certain kinds of small arms and the influence they are now exercising in European affairs are at present receiving a large share of public attention, we think that it may not prove uninteresting to bring before our readers some matters of scientific interest in connexion with our own "great guns," and the means employed for ascertaining by photography, and with the utmost possible precision, not only the path of a projectile in the air, but the time occupied in its progress between two or more points anywhere in the course of its flight.

It will be obvious that, when it is desired to obtain a photograph of a gun at the moment of discharge, the gun itself must be made subservient to the exposing and covering of the sensitive plate. It is impossible that any person, however delicate his eyes and ears may be, can operate so dexterously as to stop the exposure when the ball has been projected, say a few inches from the muzzle of the gun, and when it is, consequently, traveling at its greatest velocity. This can only be accomplished by automatic arrangements, aided by electricity.

Let us now suppose that a stereoscopic camera, fitted with powerful lenses of short focus, has a thin light disk fitted up in front of the lenses, revolving on an axis between the two lenses. Two holes in this disk correspond with the apertures of the lenses, so that if a circular spring—like that of a pair of snuffers—cause the disk to make half a revolution with great rapidity, the holes or apertures will, when flashing past the apertures of the lenses, admit the light for an exceedingly brief period of time. This is the means employed in the Arsenal for effecting the exposure of the plate.

We shall now enter into the details of the manner of discharging and arresting the circular exposing diaphragm. The opening and shutting of the camera at the precise instant of time is, as we have said, by far too nice an operation to be accomplished by hand. It must be borne in mind that a gun commences to recoil as soon as the projectile is fairly clear of its muzzle. The picture which we examined had been taken while the projectile was yet emerging from the gun's mouth, and before it had got quite clear of it, and consequently before the recoil of the gun had commenced. The exposure was very rapid, but not so much as to show the front edge of the emerging projectile, with a sharp outline. Although the gun, from the recoil not having

commenced, was quite sharp, the front edge of the projectile was, so to speak, vignetted.

The gun is fired by means of the galvanic tube invented by Mr. M'Kinlay, and such as is used in proving ordnance. Inside of this there is a small platinum wire, which, when a current of electricity is passed through it, instantly becomes red-hot and melts. Let us now see how this affects the operation of photographing the gun. When the gun is ready for firing, the disk in front of the lenses is wound up, so that the rotating force of the spring in the centre is at its maximum. It is retained in this position by means of a catch and trigger, (which we shall presently describe,) the latter of which is operated on by means of an electro-magnet. The following, then, is what takes place: When the galvanic current is sent through the wire, the fine platinum wire imbedded among the gunpowder of the discharging tube or fuse immediately becomes red-hot and melts. But while in process of melting it accomplishes two things—it transmits a current through it by which the electro-magnet becomes vivified and pulls the discharging trigger of the disk in front of the camera lenses; and, secondly, it ignites the gunpowder and discharges the gun. But were this all, the exposure would be made before the powder had time to ignite and consequently discharge the gun; hence it is important that the lenses be kept open until the gun really discharges its contents. The means for effecting this are as simple as they are ingenious and complete. When the trigger acts so as to release the disk from its enforced pent-up condition, it is propelled forward by the central spring until the apertures in the disk and those of the lenses coincide, where, by means of a stop, the disk is retained until the powder is ignited and the gun discharged, when, the platina wire being ruptured, the passage of the electricity is stopped, the electro-magnet simultaneously losing the power by which it was enabled to arrest the rotary progress of the disk, which thus darts forward and closes up the camera as the contents of the gun are in the act of being ejected from it.

Latest Discovery in Electricity.

From the Practical Mechanic's Journal, June, 1866.

In the course of some experiments with a magneto-electric machine of rather peculiar construction, it has been discovered by Mr. Wilde that if the induced current from the armature were made to pass through the coils of an electro-magnet, the magnet attained more than four times the lifting power of the permanent magnet from which the force was at first obtained, and, as it would appear, *prima facie* in opposition to the laws of conservation of energy. Mr. Wilde has thus expressed himself: "Having discovered the fact that a large amount of magnetism can be developed in an electro-magnet by means of a permanent magnet of much smaller power, and as definite quantities of magnetism are accompanied by the evolution of proportionate quantities of dynamic electricity, and since an electro-magnet, when ex-

cited by means of a voltaic battery, possesses all the properties of a permanent magnet, it appeared reasonable to suppose that a large electro-magnet, excited by means of a small electro-magnetic machine, could, by suitable arrangements, be made instrumental in evolving a proportionately large quantity of dynamic electricity, notwithstanding the pulsatory character of the electricity transmitted through the wires surrounding the magnet." The accompanying figures will afford a tolerably clear idea of the apparatus Mr. Wilde employed at the beginning of his experiments. The cylinder C C has a truly bored hole, A, in its centre. The cylinder is composed of two slabs of cast iron, C C, which are separated from each other by bars or strips, B B. Screws are inserted through the slabs and strips by which these are held together. A number of permanent magnets, one of which is represented by D D, are placed over the cylinder, and these magnets are formed so as to grip the cylinder tightly, thereby making good contact. The iron sides, under these conditions, become the poles of a powerful magnet, which are increased in power as one magnet after another is added. Within the hole A, Fig. 1, an armature is made to rotate. This armature is shown in section and elevation at Figs. 2 and 3. In the armature two deep grooves are cut, and wire is wound longitudinally over it, as at M N, Fig. 3. From the construction it will be evident that, as the armature is made to rapidly revolve in the hole A, its magnetism will be reversed twice in each revolution, and its surrounding wire will give off electrical currents as with an electro-magnetic machine of the usual form. The armature was driven at the rate of 3000 (or thereabouts) revolutions per minute by means of a small steam engine. At this velocity 6000 waves of electricity would be given off, each alternating in opposite directions. Where a commutator, however, is attached to the machine, the currents would then be all sent in one direction. In one of the earliest experiments with this apparatus the wires of the armature were connected with a tangent galvanometer, to measure the amount of electricity evolved. One magnet, weighing about one pound, was first placed on the cylinder, and three other magnets of the same size were added in succession. It was found that the amount of electricity given off was directly proportional to the number of magnets on the cylinder. When the electricity obtained from one of these four permanent magnets was made to pass through the coils of an electro-magnet, the latter lifted nearly four times the weight of the former. This induced Mr. Wilde to make a second cyl-

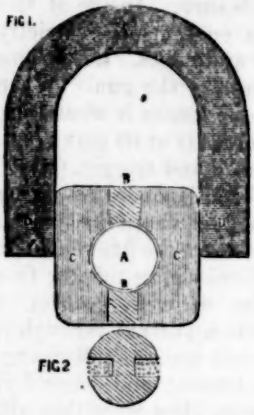
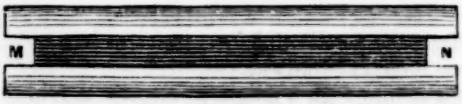


Fig. 3.



inder, and place it in contact with electro-magnets excited by the first machine, a very powerful current being the result. Lastly, he added a third machine, with a cylinder of 10 inches internal diameter, and when the three pieces of apparatus were connected together, and the armatures made to revolve, quantities of electricity far exceeding that obtainable by any other means hitherto used were given off. The illuminating power of the current thus obtained was of the most splendid description. Two carbon electrodes, half an inch square, were placed in the holders of the electric lamp, and a parabolic reflector was fixed so that the rays should diverge at a considerable angle. With this arrangement placed on the top of a lofty building, "the light evolved from it was sufficient to cast shadows from the flames of the street-lamp a quarter of a mile distant upon the neighboring walls." When viewed from that distance the light was a magnificent object to behold, having all the rich effulgence of sunshine. The calorific power of the current was so great that it melted pieces of cylindrical iron rod, 15 inches long, and ¼ inch diameter. It melted 15 inches of No. 11 copper wire 0·125 of an inch thick, and with another arrangement of the armatures melted 7 feet of No. 16 iron wire 0·065 of an inch in diameter, and made 21 feet of the same wire red-hot. The most remarkable fact of all is that the primary permanent magnets weigh only one pound each, and the current they give is insufficient to melt the shortest piece of iron wire, yet, by the intervention of electro-magnets as described, a current of extraordinary power is produced. The third machine made, which was the largest, had a cylinder with a 10-inch bore. The whole machine is only 80 inches in length, 24 inches wide, 60 inches high, and weighs 4½ tons. The smaller cylinders of the other machines were 2½ inches in diameter. The whole of them, therefore, occupy very little space, and although they are heavy the only moving portions of them are the armatures. The invention, therefore, seems likely to be of special value for light-house illumination, and for other purposes which as yet it is impossible to foresee. This *most important* discovery of Mr. Wilde was brought before the Royal Society, at a recent meeting, by the distinguished Michael Faraday.

Safety Gunpaper.

From the London Mechanics' Magazine, April, 1866.

The inventive genius of man is as constantly developing itself in the direction of munitions of war as it is in that of implements of peace. As we are called upon from time to time to record some vast stride in the improvement of machinery the object of which is peace and the conservation of human life, so have we occasionally to chronicle the advent of some weapon or material the mission of which is war and destruction. We have gunpowder, gun-cotton, gun-saw-dust, and now we add to this category a new material—gunpaper. Now, however lightly we may esteem the lives of those against whom we are to try the force of these various explosive compounds, we are apt to have a

somewhat higher regard for our own. Hence the object has always been to obtain a material embodying a maximum explosive power, and which, at the same time, shall carry with it a minimum of danger to the user. In gun-cotton we obtain the first-named element in a marked degree, but unfortunately not the last, and this has led to the Austrians recently clearing out their stores of gun-cotton and returning to their old love—gunpowder. This fact of insecurity to life being the inherent condition of all explosive compounds has been the basis of attempts to render them explosive and non-explosive at will, and the attempts have succeeded; but success has been purchased at too great an expense—the portability of a given mass of gunpowder is vastly decreased, and its usefulness on an emergency sadly impaired. So, from one cause or other, the powder-protecting schemes have passed away to that land which is constantly receiving fresh accessions of useless ingenuities. But besides exercising itself in rendering existing explosive compounds safe to handle and transport, ingenuity has been endeavoring to achieve a far better result. It has striven to produce a material which, with all the elements of destruction in its nature, should yet embody the much desired principle of safety. And, in these respects, the safety gunpaper, as now presented to us, certainly appears to succeed in a marked degree. It combines highly penetrative power with a safety which, if not absolute, is, at any rate, far superior to that of either gun-cotton or gunpowder.

This gunpaper is the introductien of Mr. G. S. Melland, of 38 Lime Street, London, who is well known as having been the means of introducing many new things in fire-arms, the Snider breech-loader and the Jocelyn rifle amongst others. It consists of paper impregnated with a composition formed of the following ingredients: Chlorate of potash, 9 parts; nitrate of potash, $4\frac{1}{2}$ parts; prussiate of potash, $3\frac{1}{4}$ parts; powdered charcoal, $3\frac{1}{4}$ parts; starch, $\frac{1}{2}\frac{1}{1}$ part; chromate of potash, $\frac{1}{1}\frac{1}{5}$ part; and water, 79 parts. These materials are mixed together and subjected to an hour's boiling; the solution is then ready for use, and the paper is passed in sheets through the mixture. The saturated paper is now ready for manufacturing into the form of a cartridge, and is rolled into compact lengths of any diameter, from that of a small revolver to that of a 600-pounder. These rolls may be made of the exact length required for each charge, or they may be made a foot, or even a yard long, and be afterwards cut up to suit the charge. After rolling, the gunpaper is dried at a temperature of 212° Fahr., when it presents the appearance of a compact grayish mass, resembling nothing so much as a piece of vulcanized india rubber door spring. Some comparative experiments we have recently made with this material lead us to the conclusion that the advantages claimed for it over gunpowder are by no means imaginary or slight. It appears to afford a perfect substitute for gunpowder, superseding gun-cotton and all other explosive compounds yet tried. It is safe alike in manufacture and in use; the chemical solution is the reverse of combustible, and the paper is dried at a very low temperature. In use its manipulation is unattended by the danger

attaching to gun-cotton, it may be freely handled without fear of explosion, which is not even induced by percussive action. It is, in fact, only exploded by contact with fire or at equivalent temperatures, and is readily and accurately cut into cartridges by hand. In its action it is quick and powerful, having, in this respect, a decided advantage over gunpowder, than which it is also much cleaner in action. Its use is unaccompanied by the greasy residuum always observable in gun-barrels fired with powder, the barrels, after firing the gunpaper, being perfectly dry and comparatively clean. Its explosion produces less smoke than that of gunpowder, and it was only occasionally that we observed it to leave a slight deposit behind, and that was of a dry nature, and might, we think, be obviated by improved details of manufacture. It has less recoil, with quicker penetrative power than gunpowder, and is stated to be less liable to deterioration from damp than the latter material. It is readily protected from all chance of damp by a solution of xyloidin in acetic acid. The xyloidin is prepared by acting on paper with nitric acid, one part thereof being dissolved in three parts of acetic acid of specific gravity of 1·040.

Its advantages are substantiated by the results of the experiments to which we have alluded, in which the weapon used was one of Mr. Melland's improved revolvers. Six rounds were first fired with cartridges containing 15 grains of gunpowder and a conical bullet at 15 yards range, which gave as a result an average of $1\frac{3}{16}$ inch penetration into deal. Six rounds were next fired with 10 grains of gunpaper and a conical bullet at the same range, the result being an average penetration of $1\frac{3}{8}$ inch into deal. This shows the superior penetrative power of gunpaper to be $\frac{3}{16}$ inch over that of gunpowder at equal ranges, but with 33 per cent. less material. Six rounds were then fired with an increased charge of 15 grains of gunpaper and a conical bullet, at the same range, and at each shot the bullet passed through a 3-inch deal. But this does not represent the ultimate power of the gunpaper, as even at 29 yards range 12 grains of the paper fired from a pistol of 54 gauge (·44-inch) sent a heavier bullet through a 3-inch deal. The power of the safety gunpaper was thus proved to be far greater than that of gunpowder; how much more matters not for our present purpose. In a Snider breech-loader, charges of 2 drachms of gunpaper with a conical bullet were fired from a capsule with central fire and metal base, with equally good results, and with a comparatively slight recoil. In order to test whether the use of the safety gunpaper produced any corroding action upon the metal of the bore, we preserved a fouled revolver, and after four days we could not detect any symptoms of corrosion, or any other sign of deterioration whatever. We must not pass by one special advantage, which it occurs to us the safety gunpaper presents as applied to breech-loaders. About 25 per cent. is saved by gunpaper as against gunpowder in the length of the cartridge, and this shortening, of course, admits of a corresponding reduction in the length of the breech, thereby adding to the strength of the piece at this point, and diminishing its weight. With regard to the commercial bearing of the question, which is al-

ways an important point, we have not yet sufficient data to form an opinion. We, however, have Mr. Melland's authority for stating that, taking into account the smaller quantity required to give an equal effect, the cost of the safety gunpaper will be from 30 to 50 per cent. less than that of gunpowder. From what has already been stated, the relative merits of gunpaper and gunpowder will be clearly seen, and a very strong *prima facie* case is made out in favor of the former. It remains for time and extended application to bring out any latent defects it may possibly possess, and which could not be expected to manifest themselves at our limited trial. We trust Mr. Melland's enterprise in introducing the safety gunpaper may meet with the success it merits. As far as our knowledge of the new material and its capabilities extends, we have no reason to fear that the ultimate results will prove otherwise than satisfactory.

Pyrotechnic Experiments.

From the London Chemical News, No. 337.

On looking over a number of receipts, collected among my earlier days of chemical experimenting, I came upon a number of original receipts for colored stars, for rockets, Roman candles, and shells, which, as they were the result of many experiments, I can confidently recommend as very brilliant in color and good, and I venture to hope that not only amateurs, but even some professional pyrotechnists, may find the receipts serviceable, for even in professional exhibitions some of the colors are often sadly wanting in brilliancy.

The ingredients for each of these stars for rocket-heads, &c., is powdered separately, and then the whole is made up into a thick paste with water, which is rolled out to the proper thickness and punched into square stars and carefully dried till quite hard.

1. *Red Stars.*—Dried nitrate strontia, 4; chlorate potash, 2; sulphur, 2; black sulphide antimony, 1.

2. *Green Stars.*—Nitrate baryta, 5; chlorate potash, 2; sulphur, 2; black SbS_2, 1.

3. *Lilac Stars.*—Chlorate potash, 49; sulphur, 25; chalk, 20; black CuO, 6.

4. *Purple or Blue Stars.*—Chlorate potash, 42; pure nitrate potash, 22; sulphur, 22; CuO, 10.

With regard to the remaining receipts, I am not able to state whether they are original or not at this distance of time; still, as they are all well proved, I venture to send them, if they will not take up too much room in your journal:

5. *White Stars.*—Saltpetre, 16; sulphur, 4; black sulphide antimony, 5.

Blasting powder at 6*d.* per pound, reduced to powder, is meant in the following receipts:

6. *Tailed Stars.*—Blasting powder, 8; sulphur, 8; saltpetre, 8; coarse charcoal, 8.

Charge for two-ounce rockets.—Blasting powder, 20; charcoal, 6; saltpetre, 4. A moderate amount of blasting powder for the head to light and disguise the stars.

Composition for Roman candles between the stars lying on powder at 1*s.* 3*d.* per pound.—Saltpetre, 5; blast powder, 1½; sulphur, 1; sand, 1.

Spur Fire.—Saltpetre, 4½; sulphur, 2; finely powdered and mixed, and then gently rubbed with lamp-black, 1½; pack in cases 6 inches long and ¾ inch internal diameter.

So far for the receipts.

Having had occasion to speak of baryta and strontia, I may as well take this opportunity for mentioning a fact the discovery of which, some years ago, interested me much, and may prove interesting to such of your readers as are mineralogists, and know Clifton from its beautiful suspension bridge or otherwise. Geological books state that sulphate of baryta exists in our Clifton rocks. After much trouble in my early days I found it in the form of red veins traversing the limestone cliffs. No other sulphate of baryta, I believe, was known in the neighborhood. Sulphate of strontia, I believe, was not known to be found nearer than Aust-passage, until a quantity was found at Pylehill railway cutting, Bristol, a few years ago, and I once found some crystals at Clevedon, twelve miles distant, in the sea-cliffs. But during the last few years a number of fields running directly eastwards from the Clifton downs towards Cotham, and familiar from childhood, have been disturbed, the grass has been taken up, and numberless buildings erected. This has disclosed, lying horizontally over the upturned limestone strata forming the Clifton rocks and downs, a layer of new red sandstone of pale-yellow color. This layer abounds in masses of white pulverulent sulphate of baryta and fine crystals of sulphate of strontia.

E. A. H.

On the Combustion of Gas for Economic Purposes. By Dr. Letheby.

(A Lecture delivered before the British Association of Gas Managers.)

From the London Chemical News, No. 341.

At the close of the last lecture which I had the honor of delivering to this Association at the meeting in Birmingham, I referred very briefly to the general phenomena of gaseous combustion, and to the principles of the economic use of coal-gas. It was my intention, indeed, to have entered fully into this matter; but so much time was occupied in the examination of the chemical and physical properties of the most important constituents of coal-gas, that little was left for the consideration of this part of our subject. I have, therefore, been requested to make it the especial subject-matter of this evening's lecture; and, in order that you may follow me through the various details of the inquiry, it will be necessary to pursue it from the beginning.

The phenomena of visible combustion are always the results of ener-

getic chemical action; and the heat and light which characterize it are the consequences of the violent collisions and rapid trembling of the combining atoms. When this collision occurs by the showering down, as it were, of gaseous atoms upon a solid, as you here see in the combustion of carbon and of iron in oxygen gas, and of antimony in chlorine, there may be a very intense ignition of the solid, but there is no flame. On the other hand, when the conflict is entirely among the particles of gaseous or vaporous matter, or matter in a finely divided and mobile condition, the phenomena are altogether different; for although, as before, the atoms or molecules of the burning body are intensely heated, yet from their mobility they give rise to that appearance called flame.

In all cases, therefore, we must regard flame as gaseous, or vaporous, or very finely divided matter intensely heated. That the particles of the gas or vapor must be themselves bodily and intensely heated to produce flame is evident from this—that when I burn hydrogen, or coal-gas, or the vapor of ether, or alcohol by means of a finely divided solid, as I do here with a rosette of fine platinum wire, you see how the fire glows; but there is no flame, for the combustion is limited to the thin layer of gaseous matter which immediately surrounds the metal, and the temperature of the combustion is comparatively low. But if I raise it to a higher temperature, as will sometimes happen of itself, then the whole mass of escaping gas or vapor is thrown into a state of ignition, and it bursts into flame.

Let us pause for awhile to study the complicated nature of this phenomenon. Whenever a gas or vapor burns in an atmosphere of another gas or vapor, as we here see in the flame of the burning gas and candle, the phenomena are very complicated. At the points of contact which are now at the outside of the flame, the collision of the particles, because of their rapid chemical union, is most violent; and here, therefore, we have the highest temperature; but as a portion of the outer atmosphere penetrates for some distance into the burning gas, it extends the conflict into the body of the flame, and there finding itself in the presence of complex particles, it closes with those whose energies are most active. In this manner the hydrogen of the hydro-carbon is burnt first, and the liberated carbon, standing for awhile in an ignited state, forms the luminous shell of the flame; and within, waiting for the presence of air, or rather passing out to take part in the conflict, is the unchanged gas or vapor. Every common flame, therefore, consists of at least three parts: The inner layer of unchanged gas or vapor, next the shell or cone of luminous matter, and, lastly, the outer shell of perfect combustion. That there is always an inner portion of gas or combustible vapor in every common flame may be proved by drawing it out with a glass tube and burning it at the end. See how I do it here with the flame of burning ether, and the same may be done with all other flames.

And now we are prepared to ask why it is that different substances burn with such different degrees of luminosity. The answer is clearly to be found in the circumstance that different substances contain, or

evolve, or produce different amounts of solid particles. In all these flames of hydrogen, and sulphur, and carbonic oxide there are no solid particles to be heated; but in this gas, and candle, and paraffin lamp the particles of soot or carbon are very numerous, and if it so happens that the products of the combustion are also solid particles, the intensity of the light is so much the greater. Look at the splendid combustion of phosphorus in oxygen, and of magnesium in air. In both cases you will notice that the products are a white powder, every particle of which at the moment of its formation is intensely heated. It follows from this that every circumstance which increases the number of solid particles, within a reasonable limit, or which prolongs the time of their ignition, or which exalts the temperature of it, increases the light of the flame, and, conversely, everything which destroys the particles or lowers their temperature will also destroy the light.

If I throw the solid particles of lime into this almost invisible flame of oxygen and hydrogen, you will notice how vividly I bring out the light; and so, also, if I give the vapor of a hydro-carbon, as benzole, which is rich in carbon, to the hydrogen by merely passing it through a tube packed with tow, and moistened with naphtha, you observe how brightly the hydrogen burns. In the same way we can increase the illuminating power of coal-gas by passing it into a chamber containing naphtha; and experiment shows that with common 13-candle gas the illuminating power is increased about 4·5 per cent. by every grain of naphtha to the cubic foot.

On the other hand, if I destroy the solid particles by hastening their combustion, the light of the flame is diminished. Here, with a common Argand burner, I merely increase the flow of air to the gas by lengthening the glass chimney, or by enlarging the central aperture, or by driving the gas by great pressure through small openings, and you see how I destroy the light; and, worse still, if I mix air with the gas, so that the particles of carbon find themselves at once in the presence of atmospheric oxygen, there is no light at all. Let me blow out the gas-flame from this Argand burner, and put a piece of wire gauze upon the top of the glass chimney. The gas will now draw in the air and mix with it before it reaches the top of the chimney, and see how the light is destroyed. The same is the case with this burner of Professor Bunsen. It is a metal tube of 5 or 6 inches in length, and from $\frac{1}{2}$ to 1 inch diameter; the gas is admitted through a small aperture at the bottom of the tube, and just below this point there are four or five openings for the admission of air. As the gas issues from the jet and passes up the tube, it draws in the air, and this, mixing with the gas, burns at the top of this tube without any light, but with great heat. This indicates to us the disadvantage of allowing air, even in small proportion, to get into the gas; in fact, experiment shows that with common 12-candle gas, the loss of light with different proportions of air will be as follows:

Loss of Light from Air in Gas.

Per cent. Air.	Loss per cent.	Per cent. Air.	Loss per cent.
1	6	8	58
2	11	9	64
3	18	10	67
4	26	15	80
5	33	20	93
6	44	30	98
7	56	40	100

The practical conclusions from these inquiries are, that gas must be burnt with such a proportion of air as that, on the one hand, the particles of carbon shall be intensely heated, and shall remain as long as possible in an ignited state, and, on the other hand, they must not escape unburnt.

Relative luminosity of different burners, calculated for the same consumption.

Kind of Burner.	Pressure at Burner.	Relative value per foot Gas.
Single jet	0·50	100
Fishtail	0·25	146
Bat's wing	0·18	153
Argand	0·17	198
Bengal	0·13	214

Relative luminosity of jets of different sizes calculated for the same consumption.

Size of jet, Inch.	Pressure at Burner.	Relative value per foot Gas.
0·040	0·87	100
0·056	0·35	120
0·083	0·12	136
0·100	0·04	150
	Fishtails.	
0·036	0·47	100
0·045	0·39	194
0·056	0·24	293
0·062	0·39	319
	Bat's wings.	
0·008	1·19	100
0·012	0·49	184
0·016	0·24	232
0·020	0·16	293
0·024	0·11	313
0·028	0·09	322
0·032	0·07	316
0·036	0·04	310
0·040	0·03	307

The difficulties in arriving at these results are almost insuperable, for every illuminating agent has its own particular conditions, and requires its own especial appliances to bring out the fullest effects.

Take, for example, the effect of different kinds of burners, each burning at its best, with the same gas, (13-candle.)

Argands of 15 holes and 7-inch chimney, consuming 5 cubic feet of gas per hour.

Size of Inner Hole.	Pressure, Inch.	Relative value per foot Gas.
0·70	0·66	100
0·57	0·46	108
0·48	0·17	117
0·44	0·17	120
0·43	0·17	115
0·42	0·17	110

Relative luminosity of the same jet (0·04 inch) at different pressures, calculated for equal consumptions.

Consumption per hour, Cubic Feet.	Pressure, Inch.	Relative value per foot Gas.
0·88	0·28	100
1·31	0·43	156
1·80	0·87	195
2·33	1·38	240
2·83	1·97	264
3·53	2·68	270
Fishtails, (0·03 inch holes.)		
2·00	0·17	100
3·00	0·34	109
4·00	0·50	111
5·00	0·74	110
6·00	1·00	95
Bat's wings, (0·015 inch slit.)		
2·00	0·13	100
3·00	0·21	109
4·00	0·29	135
5·00	0·45	128
6·00	0·53	122
7·00	0·68	121
Sugg's Argand 15 holes, (0·45 internal diameter; hole, 0·05 inch.)		
2·0	0·04	100
3·0	0·08	143
4·0	0·12	183
5·0	0·17	202
5·5	0·18	201
6·0	0·19	196

Again, the same kind of burner, but of different sizes, will give different values.

And, again, the same burner with different pressures, and, therefore, different rates of consumption, will give different values, when calculated for the same quantity of gas.

And so also with cannel gas, although in many cases the variations are not so great as with common gas, yet they are sufficiently considerable to be serious. This is seen by the following table, which I have drawn up from the experiments of Mr. King, of Liverpool:

Relative illuminating power of cannel gas, when burnt from different burners, and in different quantities from the same burner.

Power in sperm candles (120) *per foot of gas.*

Kind of Burner.	1 ft. per hour.	2 ft. per hour.	3 ft. per hour.	4 ft. per hour.	5 ft. per hour.
Single jet	2·64	...	...	...	...
Lancashire fishtail, (No. 2)	3·23	3·59	3·66	...	...
" " (No. 4)	3 59	3·95	4·11	4·0	...
London " (No. 2)	3·49	3·61	3·89	3·85	...
Bat's wing	3·09	3 76	4·05	4·11	4·16
Sixteen-hole Argand	0·26	1·74	2·43	3·53	3·68
Winfield 28-hole Argand	0·28	2·04	3·09	3·57	3·77

What, then, is to be done in the apparent confusion of all these facts, and can any useful generalization be made of them?

In the first place, we perceive that, of all kinds of burners, the single jet is the least effective.

Secondly, we notice that, although the bat's wing and fishtail burners are not subject to so great variations in power as others, and are, therefore, best suited for common use, yet they require certain precautions to be fully effective. The best burners are those which consume from 3 to 5 cubic feet of gas per hour, and the slits and holes should be so graduated that the gas issues at a pressure of from 0·08 to 0·12 of an inch for very poor gas, (12-candle,) and from 0·20 to 0·40 for 14-candle gas, and from 0·4 to 0·6 inch for cannel gas.

Thirdly, we find that Argand burners are only fit for gas of less than 18 or 19-candle power. For very poor gas, (up to 13-candle,) the best form of Argand burner is the porcelain Argand of France, (the Bengal,) which has the following measurements:

Bengal burner (Argand) of 30 holes.

Total height of burner	3·150 inches.
From gallery rest to top	1·220 "
External diameter	0·886 "
Internal "	0·354 "
Diameter of circle of holes	0·650 "
" of holes	0·024 "
Height of glass	7·87 "
External diameter of glass	2 00 "

The flame is protected from currents of air by a cage or basket of porcelain below, which is pierced with 109 holes of the 0·118 of an inch in diameter. This burner requires a pressure of from 0·15 to 0·25 for the proper consumption of the gas, and the rate at which it burns never exceeds 3·5 cubic feet per hour. This is the standard burner for France, and, compared with the best English burners, the value of the light for 5 cubic feet of 13-candle gas is as 113 is to 100.

In this country the best form of Argand burner is the 15-hole steatite burner of Mr. Sugg. The measurements of it are as follows:

Sugg's steatite (Argand) of 15 holes.

Total height of burner	3·00 inches.
From gallery rest to top	1·10 "
External diameter	1·10 "
Internal	Variable according to quality of gas.
Diameter of circle of holes	0·80 inches.
" of holes	0·06 "
Height of glass	7·00 "
External diameter of glass	2·00 "

The flame is protected by a perforated metal disk placed under the gallery, the perforations being 0·08 inch in diameter, and 8 in the inch linear.

The diameter of the inner hole or air-channel should vary according to the power of the gas, thus:

For 12-candle gas	0·44 inch.
" 14 "	0·48 "
" 16 "	0·55 "
" 18 "	0·60 "

All these Argands have the holes the 0·06 of an inch diameter, and the pressure is only 0·07 of an inch instead of 0·17, as with the old Sugg of 0·04 diameter. Above 18 candles, the bat's wing is the best burner for educing the light, and it should be regulated from 4·5 feet to 4 feet, according to the richness of the gas. And now, before I leave this part of the subject, I will show you some of the contrivances which have been proposed for increasing the illuminating power of a poor gas.

You have already seen that the single jet gives proportionably less light than the double jet or fishtail, and this is because of the larger surface of the flame exposed to oxidation. In this experiment, when I bring the jets together, you will notice how the light is at once increased, the proportion of increase being shown in the diagram.

Relative illuminating power of jets separate and together.

		Relative value per foot of gas.	
Size of Jet, Inch.	Pressure, Inch.	Separate.	Together.
0·067	0·24	100	164
0·083	0·20	100	190
0·100	0·12	100	184

But the pressure may he such as to spread out the flame too much, and then it is over oxidated. To check this there are the contrivances of Hart, Williamson, and others, which are fishtail burners attached to a box stuffed with wool, or having a small aperture within, as compared with the aperture without. This offers resistance to the flow of the gas, and by making it tail a little it thickens the flame and brightens the light; but the same effect would also be produced by altering the tap, provided the tap is placed, as it always should be, at a distance of about 18 inches from the burner; in fact, if it is nearer than this, as is generally the case, there is no space or chamber for the equalization of the pressure, and the gas always burns at a disadvantage.

Again, there are contrivances on the outside of the burners—as caps, and rings, and thickenings of the top of the jet—whereby the flow of air to the gas is checked and oxidation diminished.

Even with the Argand burner, if the gas is over oxidated, as by burning it with too large an inner aperture, or with too high a chimney, or at too small a rate, the light is improved by checking the draft of air; and this may be done, as you see, by putting a cap of wire gauze over the chimney. In fact, the whole of these contrivances have for their object such an adaptation of the gas to the air, or the air to the gas, as that the flame is just short of smoking. Under these circumstances, the solid particles remain as long as possible in an ignited state, and yet at last they are perfectly consumed.

(To be continued.)

Effect of High Heat on Compound Gases.—M. H. Sainte-Claire Deville, by a series of beautifully devised and carefully executed experiments, has shown the curious fact that at very high temperatures, such as are obtained in the wind furnace or the oxyhydrogen blowpipe, gases, which have at more moderate temperatures the highest affinity for each other, become indifferent, and, if already united, separate, so that at these temperatures, for instance, steam separates into oxygen and hydrogen. To this curious and very important phenomenon he has given the name "dissociation." M. Cailletet reports to the Academy of Sciences of Paris (April 16, 1866) a series of observations made upon the gases of the iron furnace which fully confirm M. Deville's conclusions, and are of themselves of the highest importance. Thus at a distance of 8 inches inside of the tuyere hole, where porcelain and platinum were instantly melted, the gases showed 15·24 per cent. of uncombined oxygen, 1·8 of free hydrogen, and 77·86 of nitrogen; while of compounds there were but 2·1 of carbonic oxide, and 3 of carbonic acid. And when we remember that the gases had to be cooled to the ordinary temperature before analysis, and that however rapidly this operation is performed there is still time for partial combination, it would appear to assume that in the presence of free carbon at hydrogen, at the heat of fusing platinum, oxygen remains uncombined. The results were confirmed by a second series of experiments in a welding furnace. The following are the results

In the first series the gas was taken immediately above the grate, porcelain melting rapidly; in the second, 15 meters (50 feet) above the grate, between the melting point of copper (1900°) and antimony, (824°;) in the third series the gases were taken at the same point as in the second, but allowed to cool more slowly.

	I.	II.	III.
Oxygen	12 74	7·65	1·21
Carbonic oxide	2·71	3·21	1·42
Carbonic acid	2·62	7·42	15·02
Nitrogen	81·93	81 72	82·35

MISCELLANIES.

Exceedingly Hard Iron.—The *Mechanics' Magazine* says; Some years ago M. Gaudin found that by heating iron, tolerably free from carbon, with a small quantity of boron, to a very high temperature, he obtained a product which could not be forged, but which possessed extraordinary hardness. He has now found that an equally hard metal may be obtained by adding to ordinary cast iron, in fusion, phosphate of iron and peroxide of manganese—he does not mention in what proportions. The product cannot be forged, but it casts easily, and is therefore readily applicable to the construction of such machines, or parts of machines, as require in their material extreme hardness rather than tenacity. The metal so produced is, moreover, singularly sonorous, and M. Gaudin accordingly proposes it as a material for bells. He finds that a still harder metal is producible by the addition of tungsten —again he omits to say in what amount—to ordinary cast iron. He states that this tungsten iron surpasses everything previously known as a material for tools for cutting rocks, and that crystals of it will cut glass as readily as the diamond.—*Jour. Soc. Arts*, No. 685.

Artificial Ivory.—We learn from the *Les Mondes* that an artificial ivory is made in France by M. Dupré from a simple paste of *papier maché* and gelatine. Billiard balls formed of this material, though barely a third of the price of those made from real ivory, are yet so durable and elastic, that they can be thrown from the top of a house on to the pavement or violently struck with a hammer without injury. With this same paste, to which the name of Parisian marble is given, among many other things, the finest and most complicated mouldings for ceilings can be made, or capitals of columns can be constructed in any color, so as to resemble the most valuable marbles.—*Lond. Reader.*

New Process for Engraving.—I see a simple way of engraving intended to replace wood-cutting, which I will quote from *Les Mondes.* The inventor starts with a smooth plate of chalk, on which he makes his

drawing with gum-water or something else that will harden on the chalk. He then sets to work with a hard brush and scrubs out the soft part not drawn on, and so gets his design in relief. He subsequently hardens the plate by putting it in a bath of gelatine and then drying it.—*Chem. News*, No. 289.

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Action of Gelatinous Phosphate of Lime.—M. Collas dissolved some isinglass in water, and divided the solution into two parts. With one he mixed a little gelatinous phosphate of lime; the other he set aside as it was. Each as it cooled became a jelly, but that containing the phosphate soon liquefied, and in thirty-six hours began to putrefy, while the simple solution of isinglass remained sweet for six days. The author made a corresponding experiment with fresh beef, and found that the admixture of phosphate accelerated putrefaction. The author is of opinion that the value of phosphate of lime as manure must be in part attributed to this action. Buried in the soil it comes in contact with nitrogenized matters, and decomposes them, rendering them soluble and easy to be absorbed by plants. It must not be considered as a passive body, simply necessary for the organization of the plant. It is also a powerful stimulant to vegetation, preparing itself the nutriment of the plant. The easy digestibility of fish the author considers to be owing to the presence of phosphate of lime, and he suggests that beef and mutton may be rendered much more digestible by adding gelatinous phosphate of lime to them. M. Collas believes, in fact, that an immense amount of good may be done by administering phosphate of lime in the form of gelatinous hydrate.—*Les Mondes.*—*Chem. News*, No. 329.

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Ingredients to Atmospheric Air.—H. Reinsch stretched 18 square feet of carefully washed linen cloth upon poles, so as to form a sort of roof. Over one such roof he allowed very dilute hydrochloric acid to trickle for fourteen days, and over another a 1 per cent. soda solution for the same time. The collected liquors were then evaporated and examined. The acid liquor was first distilled. A beautiful violet-colored (an analine?) compound passed over first, then sal ammoniac, and last, some pyrogenous products arising from the organic substances absorbed by the acid. The residue was then completely carbonized, and the ash examined. It contained traces of metals precipitable by H_2S, (Pb, Sn, or Cu?) The aqueous extract of the ash contained Na, considerable traces of Ca and K, and doubtful traces of Mg. The hydrochloric solution of the ash contained Ca, Fe, Mn, Al, and traces of SO_3. Silica remained behind insoluble. In the collected soda liquor the author found much Cl and CO_2, with decided traces of PO_5 and SO_3. There were also traces of Ca, and much organic matter, with Fe, Mn, and SiO_2.—*N. Jahrb. f. Pharm.*, 24, 193. *Zeitsch. f. Chem.*, 1866, 31.

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Improved Candles.—The late Dr. B. F. Joslyn, more than twenty years ago, gave to tallow candles a thin coating of wax, which prevented the running down of the melted tallow, and enabled a small wick to be

used, as in wax candles; and thus the use of snuffers was rendered unnecessary, and smoke was avoided. He found that a pound of tallow, properly burned, gave more light than a pound of wax. The only objection to such candles is, that there is a cup of melted tallow at the top, which may be spilled if carelessly handled. The reason of this invention is this: Tallow melts at a temperature so low that the heat of the flame melts it at a considerable distance; the capillary attraction of a small wick is therefore insufficient to draw up the melted tallow fast enough to make a good light; it is, therefore, necessary to use a thick wick. But the thick wick will not bend over, so that the air may touch it, and supply oxygen to burn it; it therefore has to be snuffed. But when the outer film is wax, it does not melt easily, but holds the tallow, so that the flame may burn close to its surface, and a small wick has sufficient capillary attraction to draw up all the tallow required for a bright flame. Some years ago a chemist in Venice made candles that melted at a higher temperature than wax, and offered them as a great improvement, in that they would not drip, to be used in churches.—*Prac. Mech. Jour.*

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Free Laboratory in France.—About a year ago MM. Fremy and Chevreul started a laboratory in France in which poor and ardent students might work, and have the advice of the two worthy professors named, gratis. M. Duruy, the Minister of Instruction, has recently made a grant of 10,000 francs, and M. Ménier has offered to supply the chemicals for nothing, and thus the cost of the establishment has been provided for, although the professors still superintend it without fee. The generosity of M. Ménier does not end with the supply of the chemicals; it is said that a few students who show special aptitude for research receive pecuniary assistance from a fund which he has placed at the disposal of the professors.—*Mec. Mag.*, July, 1865.

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Method of Fracturing Cast Iron with Water.—Advantage has recently been taken of the non-compressibility of water to effect the reduction of large masses of cast iron in France. The method of producing the fracture is both simple and ingenious. It consists in drilling a hole in the mass of cast iron for about one-third of its thickness, and filling the hole with water, then closing it with a steel plug which fits very accurately, and letting the ram of a pile-driver fall on the plug. The first blow separates the cast iron into two pieces.—*Mec. Mag.*, March, 1866.

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Indestructible Bottle Labels.—Bottle lables may be made indestructible by coating them with white of egg, and steaming them until they become opaque, and then drying them in an oven at 212°. The albumen becomes hard and transparent, and is unaffected by oils or acids. —*Mech. Mag.*, August, 1865.

A Comparison of some of the Meteorological Phenomena of JULY, 1866, *with those of* JULY, 1865, *and of the same month for* SIXTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57¼′ N.; Longitude 75° 11¼′ W. from Greenwich. By PROF. J. A. KIRKPATRICK, of the Central High School.

	July, 1866.	July, 1865.	July, for 16 years.
Thermometer—Highest—degree,	101·00°	97·00°	101°
" date,	17th.	7th.	17th, '66.
Warmest day—mean,	92·33	87·33	92·33
" " date,	17th.	28th.	17th, '66.
Lowest—degree,	64·00	63·00	53·00
" date,	10th & 21st.	14th.	2, 3, '62; 3, '57.
Coldest day—mean,	69·00	70·00	59·70
" " date,	21st.	14th.	3d, '57.
Mean daily oscillation,	15·37	12·13	15·60
" " range,	4·22	4·44	3·84
Means at 7 A. M.,	76·23	74·76	73·91
" 2 P. M.,	87·31	83·44	83·67
" 9 P. M.,	78·63	76·66	76·41
" for the month,	80·72	78·29	78·00
Barometer—Highest—inches,	30·072 ins.	30·141 ins.	30·212 ins.
" date,	2d.	31st.	5th, '59.
Greatest mean daily press.	30·015	30·078	30·197
" " date,	2d.	31st.	5th, '59.
Lowest—inches,	29·501	29·587	29·443
" date,	23d.	17th.	19th, '51.
Least mean daily press.,	29·560	29·598	29·462
" " date,	23d.	17th.	30th, '56.
Mean daily range,	0·088	0·089	0·093
Means at 7 A. M.,	29·792	29·766	29·831
" 2 P. M.,	29·757	29·752	29·802
" 9 P. M.,	29·773	29·771	29·819
" for the month,	29·774	29·763	29·817
Force of Vapor—Greatest—inches,	0·980 in.	0·917 in.	0·983 in.
" date,	17th.	25th.	26th, '54.
Least—inches,	·431	·342	·255
" date,	11th.	10th.	22d, '64.
Means at 7 A. M.,	·667	·614	·612
" 2 P. M.,	·638	·605	·606
" 9 P. M.,	·696	·635	·639
" for the month,	·667	·618	·619
Relative Humidity—Greatest—per ct.,	89·0 per ct.	90·0 per ct.	97·0 per ct. often.
" date,	22d.	25th.	
Least—per ct.,	36·0	37·0	26·0
" date,	31st.	9th.	23d, '56.
Means at 7 A. M.,	72·7	70·2	72·3
" 2 P. M.,	49·3	53·3	52·6
" 9 P. M.,	70·1	68·2	69·9
" for the month	64·0	63·8	64·9
Clouds—Number of clear days,*	12	10	7·3
" cloudy days,	19	21	23·7
Means of sky cov'd at 7 A. M.,	41·6 per ct.	57·4 per ct.	58·2 per ct.
" " " 2 P. M.,	51·6	62·6	58·9
" " " 9 P. M.,	40·7	40·6	41·5
" " for the month	44·6	53·5	52·9
Rain—Amount,	2·513 ins.	2·135 ins.	3·622 ins.
No. of days on which rain fell,	12	9	11·0
Prevailing Winds—Times in 1000,	s62° 57′ w ·305	s88° 42′ w ·273	s68° 41′ w ·171

* Sky one-third or less covered at the hours of observation.

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OCTOBER, 1866.

CIVIL AND MECHANICAL ENGINEERING.

For the Journal of the Franklin Institute.

Preservation of Wood in Damp and Wet Situations. By H. W. Lewis, University of Michigan.

GRADUATING THESIS.

No introductory apology for the theme of this paper is judged necessary. A few plain statements will show that the subject is one of vast though unheeded importance.

The annual drain which is exhausting our forests is startling when we remember the vast areas of our country utterly destitute of timber—when we learn, for instance, that "upon the 55,000 square miles of Illinois, there grows not a single pine large enough from which to fashion a board.* Statistics show that, in 1865, above 5,000,000,000 feet of lumber, 2,000,000,000 of shingles, and 900,000,000 pieces of lath were sold in Chicago alone.† Michigan and Wisconsin almost entirely supply that market. 6000 feet of pine lumber per acre is an average yield.‡ No formal calculation is necessary to show us that, with the present demand, a single generation will exhaust the supply those States can afford.

* Hunt's *Merchant's Mag.*, Feb., 1866, page 105.

† Lumber, 5,089,033,033 feet; shingles, 3,560,093,212; lath pieces, 938,297,743. —Hunt's *Merchant's Mag.*

‡ "An average estimate of the product of lumber of all the pine lands in the State is 6000 feet to the acre. Some sections will overrun, some fall short, of this amount." * * * "Seven years will exhaust all the pine lumber within five miles of any of the navigable rivers."—*The Pine Lands and Lumber Trade of Michigan*, page 4.